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REPORT OF THE WHITE HOUSE SCIENCE COUNCIL PANEL ON THE HEALTH OF U.S. COLLEGES AND UNIVERSITIES

HEARING

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

SECOND SESSION

MAY 15, 1986

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REPORT OF THE WHITE HOUSE SCIENCE COUNCIL PANEL ON THE HEALTH OF U.S. COLLEGES AND UNIVERSITIES

THURSDAY, MAY 15, 1986

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
TASK FORCE ON SCIENCE POLICY,
Washington, DC.

The task force met, pursuant to notice, at 9:34 a.m., in room 2325, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. FUQUA. The Science Policy Task Force today welcomes a distinguished panel of three leaders in American science policy.

The occasion is the completion of an important report by the White House Science Council entitled, "A Renewed Partnership: An Examination of Federal Government-University-Industry Interactions in U.S. Research and Higher Education in Science and Engineering." This report covers a broad range of the issues that are of critical importance to American science. Many of these issues have also been the subject of inquiry and study by our task force over the last 18 months.

The report was written by the Science Council's Panel on the Health of U.S. Colleges and Universities. Mr. David Packard served as the chairman of that panel, and Dr. Allan Bromley served as its vice chairman. The report was initially presented to Dr. John McTague in his capacity as Acting Science Advisor to the President and Acting Director of the Office of Science and Technology Policy.

The public presentation of this report comes as the Nation is observing National Science Week. It is, therefore, particularly appropriate that its conclusions and recommendations be presented publicly at this time.

We welcome the members of our distinguished panel this morning and congratulate you on the completion of a difficult and most significant task. Its importance to the future of American science is clear, and we look forward to your discussion of the specifics of the report.

Dr. McTague, we will begin with you. We will hear from all of you, and then we will open it up for questions.

STATEMENT OF DR. JOHN P. McTAGUE, ACTING SCIENCE ADVISOR TO THE PRESIDENT, AND ACTING DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT, WASHINGTON, DC

Dr. McTAGUE. Thank you, Mr. Chairman.

I would like to begin by thanking the members of this committee for the opportunity to present to you the findings and recommendations of the White House Science Council's Panel on the Health of U.S. Colleges and Universities.

The President's former Science Advisor, Dr. George Keyworth, established this panel almost exactly 2 years ago on May 3, 1984 with the charge that it "examine and make necessary recommendations for revising the principles underlying the relationships between the Federal Government and the universities, especially as they affect the U.S. ability to create the scientific and technical talent and to conduct the research needed to sustain America's leadership in industry and defense." The Panel was composed of a cross section of high-level representatives from science, the universities, and industry and included a number of prominent scientists, professors, university administrators, and business executives.

The work of this Panel is one of the numerous ongoing activities of the White House Science Council which, in itself, is but one element of a broad-based administration effort to help preserve the Nation's scientific and technological preeminence and enhance the competitiveness of U.S. industry. As the President recently stated, "Continuing strong support for our Nation's science and technology has been and will continue to be a policy of this Administration. The goals of this support are enhanced national security, improved quality of life, and increased international competitiveness. Today, more than ever before," he concluded, "we must use our technological resources aggressively in order to retain international leadership."

As recently as last evening, he released the following statement on the happy occasion and well-deserved occasion of the award to our distinguished chairman here, Don Fuqua, of the National Science Foundation's Distinguished Public Service Award:

> Perhaps more than at any time in the past, our Nation now realizes the indispensable role that science, engineering, and technology play in assuring this country's economic competitiveness, national security, and prosperity. Because of the pervasiveness of science and technology and the rise of foreign competition in technology-based industries, we understand the need to increase our investment in basic research and to identify, attract, and nurture the new talent that will maintain America's future leadership in these fields.

The report that we are discussing today has recently gone to the President, and we expect a statement from him shortly in the form of a letter to Chairman Packard supporting the broad thrust of the recommendations we are discussing this morning.

The commitment of the administration to a strong science and technology base can be seen in the measures we have taken to ensure the maintenance of a strong economy, such as reduced taxes, Federal spending restraint, and reduced regulation. It is reflected in the Congress' and the administration's strong support for increased real funding of basic scientific and engineering research, much of it at colleges and universities, an increase totaling 30 per-

cent real since 1981 and continuing in the President's proposed fiscal 1987 budget. It is apparent in the administration's reorientation of Federal R&D funding. In 1981, basic R&D—as opposed to applications or developmental R&D—constituted the smallest share of Federal R&D, only about one-fourth; by 1984, this orientation had completely reversed, with basic R&D constituting the largest share of nondefense Federal R&D, or more than one-third.

One of the most important aspects of this administration commitment to a strong science and technology base is our recognition that America has a unique dependence upon its colleges and universities both for new knowledge and for young minds trained to use this knowledge in innovative ways. The excellence of our colleges and universities has long been a cornerstone of our economic well-being, our industrial competitiveness, our national security, and the health and quality of life of our citizens, and will become even more so in the future as we confront increasing numbers of issues at the frontiers of science.

However, as the Panel has emphasized, the strength and excellence of this higher education enterprise can no longer be taken for granted. At a time when Government and industry alike are making ever greater demands on our higher education institutions for scientific research, these institutions find themselves, after more than a decade of belt tightening, with aging facilities, obsolete equipment, and growing shortages of both faculty and students in many important areas.

It is in response to these problems that the administration has undertaken many of its R&D efforts over the past 5½ years. In addition, many other sectors of society, including State governments, industry, foundations, and private individuals, have increased their support of educational institutions in recent years. This committee itself has shown a keen awareness of these problems, and I point, in particular, to your chairman's thoughtful recommendations for addressing university infrastructure needs as an example of this awareness.

Yet, as the Panel notes, while actions such as these have been of great help to colleges and universities, much remains to be done to offset the neglect of the prior decade. Increased support for university research, the Panel found, was especially necessary. However, the Panel wisely observed that such increased support, in itself, would not be enough to ensure the health of our system of higher education. What is most needed, the Panel argued, is a reexamination of the relationships that have evolved among the Federal Government, the universities, and American industry.

In preparing for such a reexamination, it is essential that we return to the view that both Federal and industrial support of university research and education is an investment in our Nation's future, not just the one-time procurement of products and services. Moreover, we must not lose sight of the fact what while some investments in technology and ideas may be long term, in that the applications they spawn will not reach our markets or our industries for several years, perhaps the most important contribution our universities make to society is short term: the skilled and talented science and engineering graduates they produce. Without question, federally supported research does have an immediate and

beneficial impact on American strength, competitiveness, and scientific preeminence, and that impact is in people.

It was with these considerations in mind that the Panel undertook a detailed and careful analysis of how to go about developing the kind of effective Government-university-industry partnership that will be necessary if the United States is to maintain its leadership position in an increasingly technological and competitive world. In their Report, the Panel made specific recommendations to this end, and to the end of maintaining the health and vitality of our colleges and universities. Their principal findings and recommendations come with the unanimous support of the Panel members and are endorsed by the White House Science Council.

I believe that this Report deserves the thoughtful study of all the members of this committee and of the Congress as a whole, and I commend it to you for your review. Without doubt, the road ahead of us, marked out by the Panel's findings, will be a long and difficult one, and it will take many years to repair the problems the Panel has noted. But I share the Panel's optimism that, given the partnership and the approaches recommended, our universities will respond enthusiastically and effectively to the challenges ahead. And as they do, I think this Report will provide an important frame of reference against which to measure our progress and to chart next steps in our national science and technology course.

The Panel has devoted much time and effort in preparing its Report, and I would like to take this opportunity to express the administration's deep appreciation to its members. The high quality of their work is due in no small measure to the excellent leadership provided to the Panel by its chairman, David Packard, and its vice chairman, Prof. Allan Bromley. I am most honored to be able to share the stage with these two distinguished gentlemen this morning, and I look forward to their comments.

Thank you very much.

[The prepared statement of Dr. McTague follows:]

STATEMENT OF

DR. JOHN P. MCTAGUE
ACTING SCIENCE ADVISOR TO THE PRESIDENT
AND ACTING DIRECTOR,
WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY POLICY

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
SCIENCE POLICY TASK FORCE
UNITED STATES HOUSE OF REPRESENTATIVES

MAY 15, 1986

I would like to begin by thanking the members of this Committee for the opportunity to present to you the findings and recommendations of the White House Science Council's Panel on the Health of U.S. Colleges and Universities.

The President's former Science Advisor, Dr. George A. Keyworth, established this Panel on May 3, 1984, with the charge that it "examine and make necessary recommendations for revising the principles underlying the relationships between the Federal government and the universities, especially as they affect the U.S. ability to create the scientific and technical talent and to conduct the research needed to sustain America's leadership in industry and defense." The Panel was composed of a cross-section of high-level representatives from science, the universities and industry, and included a number of prominent scientists, professors, university administrators, and business executives.

The work of this Panel is one of the numerous, ongoing activities of the White House Science Council, which in itself is but one element of a broad-based Administration effort to help

preserve the nation's scientific and technological pre-eminence and enhance the competitiveness of American industry. As the President recently stated, "Continuing strong support for our nation's science and technology has been and will continue to be a policy of this Administration. The goals of this support are enhanced national security, improved quality of life, and increased international competitiveness. Today, more than ever before," he concluded, "we must use our technological resources aggressively in order to retain international leadership."

This commitment to a strong science and technology base can be seen in the measures the Administration has taken to ensure the maintenance of a strong economy, such as reduced tax rates, Federal spending restraint and reduced regulation. It is reflected in the Administration's strong support for increased real funding of basic scientific and engineering research, much of it at colleges and universities -- an increase totaling 30 percent since 1981 and continuing in the fiscal 1987 budget. And it is apparent in the Administration's reorientation of Federal R&D funding: in 1981, basic R&D -- as opposed to applications or developmental R&D -- constituted the smallest share of Federal R&D, only about one-fourth; by 1984, this orientation had completely reversed, with basic R&D constituting the largest share of Federal R&D, or more than one-third.

One of the most important aspects of this Administration commitment to a strong science and technology base is our

recognition that America has a unique dependence upon its colleges and universities both for new knowledge and for young minds trained to use this knowledge in innovative ways. The excellence of our colleges and universities has long been a cornerstone of our economic well-being, our industrial competitiveness, our national security, and the health and quality of life of our citizens, and will become even more so in the future as we confront increasing numbers of issues at the frontiers of science.

However, as the Panel has emphasized, the strength and excellence of this higher education enterprise can no longer be taken for granted. At a time when government and industry alike are making ever greater demands on our higher education institutions for scientific research, these institutions find themselves, after more than a decade of belt-tightening, with aging facilities, obsolete equipment and growing shortages of both faculty and students in many important areas.

It is response to these problems that the Administration has undertaken many of its R&D efforts over the past five and a half years. In addition, many other sectors of society, including state governments, industry, foundations and private individuals, have increased their support of educational institutions in recent years. This Committee itself has shown a keen awareness of these problems, and I point, in particular, to your Chairman's

thoughtful recommendations for addressing universities' infrastructure needs as an example of this awareness.

Yet as the Panel notes, while actions such as these have been of great help to colleges and universities, much remains to be done to offset the neglect of the prior decade. Increased support for university research, the Panel found, was especially necessary. However, the Panel wisely observed that such increased support, in itself, would not be enough to ensure the health of our system of higher education. What is most needed, the Panel argued, is a re-examination of the relationships that have evolved among the federal government, the universities and American industry.

In preparing for such a re-examination, it is essential that we return to the view that both federal and industrial support of university research and education is an investment in our nation's future, not just a one-time procurement of products and services. Moreover, we must not lose sight of the fact that while some investments in technology and ideas may be long-term, in that the applications they spawn will not reach our markets or our industries for several years, perhaps the most important contribution our universities make to society is short-term: the skilled and talented science and engineering graduates they produce. Without question, federally supported research does have an immediate and beneficial impact on American strength,

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I believe that this Report deserves the thoughtful study of all the members of this Committee and of the Congress as a whole, and I commend it to you for your review. Without doubt, the road ahead of us, marked out by the Panel's findings, will be a long and difficult one, and it will take many years to repair the problems the Panel has noted. But I share the Panel's optimism that, given the partnership and approaches recommended, our universities will respond enthusiastically and effectively to the challenges ahead. And as they do, I think this Report will provide an important frame of reference against which to measure our progress, and to chart next steps in our national science and technology course.

The Panel has devoted much time and effort to preparing its Report, and I would like to take this opportunity to express the Administration's deep appreciation to its members. The high quality of their work is due, in no small measure, to the excellent leadership provided to the Panel by its Chairman, David Packard, and its Vice Chairman, Dr. Allan Bromley. I am most honored to be able to share the stage with these two distinguished gentlemen this morning, and I look forward to their comments.

Thank you very much.

Mr. FUQUA. Thank you.

Mr. Packard, we would be pleased to hear from you.

STATEMENT OF DAVID PACKARD, CHAIRMAN, WHITE HOUSE SCIENCE COUNCIL PANEL ON THE HEALTH OF U.S. COLLEGES AND UNIVERSITIES, AND CHAIRMAN OF THE BOARD, HEWLETT-PACKARD CO., PALO ALTO, CA

Mr. PACKARD. Mr. Chairman, let me say I am very pleased to be here this morning. I think this is an extremely important subject.

I have a statement that I have prepared, and I would like to ask you to put that in the record. I am not going to read it this morning. I am going to make some comments and answer some questions.

I want to begin by saying that I have probably had as much benefit of the university-industry relationship in my professional career as almost anyone else in this country. It began 40 years ago, right after the war, when Fred Terman came back to Stanford and became dean of the school of engineering there and worked with Mr. Hewlett and me in helping to get our company started.

The basic contribution over the years has been in three basic areas. In the first place, the basic research that was done at the university and, as a matter of fact, a very large number of the products that our company was able to come out with and get ahead of the field came directly from research done at Stanford University.

The second contribution that is extremely important is education of scientists and engineers. Here, again, with our close relationship with Stanford, we were able to attract some of the bright young people from engineering and science at Stanford to join our ranks.

The third factor is one which I don't think is recognized as widely as it should be. It is a fact that science and technology are moving so fast today that it is not possible to simply get an education, get a degree in science or technology, and stop your education there. Things are moving ahead so fast that you get out of date, and the only way you can keep up with things is to have some kind of a continuing education program. Our company was able to work out with Stanford University a plan whereby our scientists and engineers could undertake continuing education. That, again, has made a very important contribution to the success that we have had.

So, I am here with really a very strong personal interest in this whole subject because it has meant so much to me.

I think you know that the development of what has become known as Silicon Valley came directly out of this relationship around Stanford. I was on the board of Trustees of Stanford from 1952 until 1968, and Professor Terman and I had a little game plan worked out where prospective people who wanted to move their companies into the area would talk to Fred Terman. He would send them over to talk to me, and we would convince them that this is the place to be. So, we had a lot of leverage in building up Silicon Valley and, as you know, that development that has been one of the most productive in our country and made tremendous contributions to our economy and our defense effort.

I would also like to point out that that was not strictly unique at Stanford. Similar developments have come about around other universities. Route 128 in Boston was built up because of MIT and Harvard's contributions there. In Pasadena and southern California, it was a result of the affiliation with Caltech, and Princeton had similar groups. So, this relationship between the universities and the development of high technology industry has been a very important asset for our country over the last several decades.

I think you know that this technology is moving ahead rapidly. The era which I have enjoyed has involved all the advances in electronics. In the future, it is going to be some different things—biological engineering, for example. But if you look at the basic source of all of these new high-technology activities, both in the past and looking toward the future, the universities play an extremely important part in all of this. They, in large part, provide the basic research, the basic knowledge. They are the only source for education of our young people to carry on this work, and they are also, as I have indicated, a very important source of continuing education so that the young people who go into this field will be able to keep up with progress.

I think you recognize that we are going through in this country what might be called a watershed change in our whole economy. The traditional heavy industries, those that relied upon natural resources, are becoming less important. We are moving into an era where the most important asset is knowledge and not material things. If we are going to keep up in this new frontier, as I am sure we must, it puts even greater emphasis on the importance of these universities because we simply will not be able to maintain our technological lead in our economy or in our national defense effort without this kind of support.

I think I really wanted to make a very strong point in emphasizing the great importance that these universities have made, the great contributions they have made.

Now, I want to say a word about what has changed over this period, because I think that may shed a little light on what might be done to improve the effectiveness of the support that the Federal Government is providing. In the early days, the support was provided largely through the Office of Naval Research. They essentially identified programs where there was important research going on where there were bright people, and they supported them on sort of a continuing basis.

They identified Fred Terman as one of the leaders in the field of electronics. They supported him first in developing some technologies, the forefront of microwaves, which involved traveling wave tubes and that technology. As the solid state program moved ahead, they supported him in a very strong program to do research on solid state technology, transistors, and, later on, large-scale integrated circuits. They provided facilities so that the young people at Stanford could not only learn the theory but they could learn how to do some of these things. The inventor of large-scale integrated circuits, Bob Noyce, whom you have heard of for a good many years came from Stanford, and it was that training and education he got at the university that enabled that whole industry to build up in that area.

Unfortunately, the trend in Federal support of universities has been similar to the trend of Federal support in a lot of other things. There has been too much micromanagement. The people in the administration have tried to second guess the people who are doing the work, and put restrictive rules, and required more reports than anybody can possibly read and understand, and I think maybe the Congress is doing a little too much of that also.

It seems to me that if we could get back to the basic concept that the support of research requires an environment of freedom so that the people who are doing the research can spend their time on research, so they don't have to spend time making unnecessary reports and meeting arbitrary rules and so forth. If we pay attention to that problem, we can get a whole lot more for our money than we are now getting in this whole area.

We recommend in our Report some things that could be done to increase the financial support. I think we recognize that the catch-up problem in terms of buildings and equipment and facilities is something that cannot be addressed completely at the present time, but there are ways that it can be dealt with over a period of time. We also recognize that because industry has been a very great beneficiary of this university research, industry has a responsibility to take a larger role in supporting it. Indeed, I think you will find that industry is doing so.

What I hope we can develop is a closer, more effective partnership relationship between the universities, between industry, and between the Federal Government. That really is the thrust of our Report, and I think with a little attention to the basic fundamentals that a very great improvement can be achieved in this all important endeavor.

Thank you very much.

[The prepared statement of Mr. Packard follows:]

STATEMENT OF
DAVID PACKARD
CHAIRMAN OF THE BOARD
HEWLETT-PACKARD COMPANY
PALO ALTO, CALIFORNIA

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

SCIENCE POLICY TASK FORCE

U.S. HOUSE OF REPRESENTATIVES

May 15, 1986

Thank you very much for the opportunity to appear before you to discuss the findings and recommendations of the White House Science Council's Panel on the Health of U.S. Colleges and Universities.

I have had the privilege and pleasure of chairing this Panel since its inception. During the time we conducted our review, we benefited greatly from the comments and suggestions of representatives from more than 100 universities and colleges and from more than 40 private sector organizations. These comments bolstered our belief that we still enjoy, in this country, the world's strongest scientific and technological enterprise. But at the same time, the comments raised disturbing problems and questions concerning both the short- and long-term health of this enterprise.

In our Report, we address these problems and questions and make specific recommendations directed to each of the Federal Government, the universities and private industry. Although we recognize that fully implementing many of these recommendations will be difficult, particularly given the continuing need to bring Federal spending under control, we are confident their implementation over time will preserve the health and

vitality of a higher education system that has served this nation well in the past, and will be even more critical in the future as the worldwide technological competition becomes increasingly intense.

Before I discuss the Report's findings and recommendations, let me emphasize that I come before you today not just as the Panel's chairman, but also as a representative of American industry. From this vantage point, I have seen first-hand the importance of enhancing America's ability to compete in world markets. It is no overstatement to say that this is one of the most serious challenges confronting the United States, and probably the most serious challenge confronting American industry. As the President' s Commission on Industrial Competitiveness concluded just last year, "Only through a competitive America can we sustain economic growth, assure our national security, maintain our leadership position in world affairs and our technological pre-eminence, and provide greater opportunities for the generations to follow."

If we are to meet this competitiveness challenge, it is critical that we preserve and expand America's science and technology base. The President's Commission underlined the importance of science and technology to this country's ability to compete when it

noted that "Without doubt, [technology] has been our strongest competitive advantage. Innovation has created whole new industries and the renewal of existing ones. State-of-the-art products have commanded premium prices in world markets, and technological advances have spurred productivity gains. Thus, America owes much of its standard of living to U.S. pre-eminence in technology." What has been true in the past will become even more so in the future, as emerging industrial, defense and health needs press the limits of our scientific and technological understanding. Therefore, if American companies are to compete successfully in the global marketplace of the 1990s, and provide the products and services that Americans need most, they will have to have ready access to the best talent, the most sophisticated scientific knowledge and the most innovative technologies.

In the United States, we depend upon our universities and colleges to educate our scientists, mathematicians and engineers and to perform the basic research necessary to our technological enterprise. Although these professionals will spend their entire careers learning, often on the frontiers of science, it is in the educational institutions that they will acquire the base of knowledge that all else they will learn will build upon. Today in the United States over 70% of our basic

research -- the kind of research that underlies all commercial applications of technology -- is conducted in the nation's colleges and universities. Hence, the U.S. higher education system plays a doubly important role in our science and technology enterprise, generating both the scientific manpower and the knowledge base.

I emphasize what may seem an obvious point in order to make clear that colleges and universities are the critical link in our nation's future competitiveness and scientific and technological pre-eminence. Without an increasing supply of talented young scientists and engineers, American industry will not be able to translate technological advances into commercial applications in a timely and competitive fashion. And without a broadening of the base of scientific knowledge, industry will not be able to respond effectively to people's future needs, emerging market opportunities, or technological challenges in cases where existing ideas or innovations are inadequate.

Historically, the United States' commitment to maintaining a strong, stable higher education system dedicated to creative scientific inquiry and exploration has permitted industry to acquire the talent and technologies necessary to carrying out these chores. Yet there are worrisome signs that colleges and universities may not be able to play this role as well in

the future as they have in the past. While the Report discusses these problems in detail, let me highlight just a few:

- The costs of research continue to increase,in most cases substantially faster than the ability of university revenues to keep pace with them. In recent years, for instance, the non-personnel costs of high-technology R&D have risen some 50% faster than the inflation rate.

- Scientific and engineering faculty salaries remain uncompetitive with those of private industry. As a result, fully one-tenth of the nation's engineering faculty positions are vacant. In critical fields like electrical engineering and computer science, some universities report half their positions unfilled.

- Universities are not producing enough new scientists and engineers. For instance, in 1983, the American Electronics Association projected that 200,000 new positions for electrical engineers and computer scientists would be created over the 5-year period ending in 1987 -- more than twice the number our universities will have graduated during that time.

- Due to long years of forced neglect, university physical plant is decaying and scientific equipment is becoming obsolete. According to the Association of American Universities, the median age of instrumentation in our nation's universities is twice that used in industrial laboratories. Universities are unable to upgrade this plant and equipment at a fast enough rate to ensure adequate future levels of scientific productivity.

It is in response to these needs and problems that the Panel produced a set of specific recommendations aimed at ensuring that colleges and universities would be able to meet the scientific and

technological demands that will be placed on them over the next several years. While I will not take your time to list all of these recommendations, which are collected in the Report's executive summary and at the end of each of its chapters, let me identify three major themes that I think flow through them.

First, the Federal Government must increase its commitment to the colleges and universities. There simply must be a greater and more focused Federal R&D effort. The Panel supported the government's present policy of channeling its R&D dollars toward basic scientific research and away from commercialization projects that are more properly the province of private industry. But this step, alone, is not enough. Over time, there must be an incremental increase in overall Federal R&D funding within the limits set by prevailing fiscal constraints. Moreover, to the extent possible, the government should establish special funds for meeting particular university problems, such as the insufficiency of science and engineering students and the decay of physical plant and equipment.

Second, the government should provide more realistic accounting and reimbursement of university research costs. The panel recommended that the Federal Government fully fund all of the research it supports, rather than demanding an arbitrary level of

"cost sharing," since, in fact, universities' continuing support of personnel, support of students and provision of an environment conducive to the conduct of research and training in themselves constitute a very real and significant cost contribution. The Panel further recommended that government agencies provide more realistic depreciation allowances for structures and equipment, establish a more uniform and equitable means of reimbursing and controlling indirect research costs, and eliminate all faculty effort reporting requirements. These steps, which merely reflect fairness, accuracy and simplicity in accounting procedures, would permit universities to cover all the costs associated with varied research projects, rather than only the most obvious ones, and would account for such costs in a far less burdensome fashion than employed at present.

Finally, and most importantly, the Federal Government should stop treating its basic research funding as an exercise in procurement and start treating it as what it is -- a long-term investment. This change in approach would greatly enhance the efficiency and creativeness of university research, while at the same time eliminating unnecessary and burdensome administrative expenses that consume increasing percentages of every research dollar. Key

elements of this investment approach that the Panel recommended be put in place are stability of funding, greater discretion on the part of researchers in the use of their research funds, and greater use by the government of block grants or contracts to support groups of investigators having shared research interests. In addition, the Panel recommended that the government continue to fund university-based, interdisciplinary, problem-oriented research and technology centers in the belief that such centers enhance creativity and the cross-fertilization of ideas by allowing university and industrial researchers to work side-by-side.

The Panel believes that if the U.S. Government, industry and higher education institutions undertake these and other steps cited in the Report, the United States will be able to restore and protect its most important scientific and technological resources -- that is, its colleges and universities. In so doing, the United States not only will ensure that it remains on the cutting edge of science and technology, but also will help ensure that American industry remains competitive far into the future.

In closing, let me emphasize again that, where recommendations urge additional funding, we recognize that fiscal constraints require that many of

these objectives be long-term rather than immediate goals. However, we urge that the government at least start -- now -- down this increasingly important path of preserving the health of America's higher education institutions. In this way our colleges and universities, so vital to building and expanding the nation's scientific and technological base, will remain as effective in the future as they are today -- the continuing envy of the rest of the world.

Thank you very much. I will be happy to answer any questions you might have.

Mr. FUQUA. Thank you very much, Mr. Packard.
Dr. Bromley.
[A biographical sketch of Dr. Bromley follows:]

DR. D. ALLAN BROMLEY

D. Allan Bromley is the Henry Ford II Professor of Physics and Director of the A. W. Wright Nuclear Structure Laboratory at Yale University. He is also President of the International Union of Pure and Applied Physics, the world coordinating body for this science.

Educated at Queen's University in Canada and at the University of Rochester in the U.S., Professor Bromley holds honorary doctorates from other universities in France, Germany, Canada, Italy, South Africa and the United States. He has been awarded the Governor General of Canada Medal, a Guggenheim Fellowship, two Humboldt Prizes and a Benjamin Franklin Fellowship in the Royal Society of Arts (London). He has served as President and Chairman of the Board of the American Association for the Advancement of Science, the world's largest scientific society.

Trained both in electrical engineering and physics, Professor Bromley is one of the world's best known nuclear physicists and one of the originators of modern heavy-ion science. As Chairman of the National Academy of Sciences Physics Survey Committee in the early 1970's he helped chart the progress of this science for the decade of the 1970's. He has been a member or chairman of national advisory committees to many Federal agencies. He serves as chairman of the US side of the Indo/US Science and Technology initiative established by President Reagan and Prime Minister Gandhi in 1982, and as a member of the US/USSR Joint Coordinating Committee for Research on the Fundamental Properties of Matter established by President Nixon and Premier Brezhnev in 1972; he is a member of the Council on Foreign Relations and of the White House Science Council.

STATEMENT OF DR. D. ALLAN BROMLEY, VICE CHAIRMAN, WHITE HOUSE SCIENCE COUNCIL PANEL ON THE HEALTH OF U.S. COLLEGES AND UNIVERSITIES, AND HENRY FORD II PROFESSOR OF PHYSICS, YALE UNIVERSITY, NEW HAVEN, CT

Dr. BROMLEY. Mr. Chairman, I, too, welcome the opportunity to appear before you this morning on this important topic. Dr. McTague and Mr. Packard have given you the broad overview of our report. With your permission, I should like to submit for the record a copy of our report which includes a detailed listing of our findings and recommendations. I should like this morning to highlight a few of those findings and recommendations.

First of all, because of the long held belief, in this country—and in many ways it is unique to this country—that higher education in science and engineering and basic science and engineering themselves are inextricably linked and symbiotic, we in this country are uniquely dependent upon our universities both for the new knowledge and for the young people trained to used that new knowledge effectively. In consequence, support of the university-based activities has both an immediate payoff in the form of the young people, and a longer term one from the research itself that the support permits.

The important thing that became clear to us during the study was that we are facing a time of unprecedented speed and scope of change taking place world wide in modern science and technology. As a consequence of that, the demands being made upon our universities have never been greater as the Nation responds to new challenges in the international marketplace, in national security, and in securing a better quality of life for all our citizens.

Just at a time when much is being expected of them, after something like a decade or more of relative neglect and, indeed, of less

than optimum management of their own affairs, as Dr. McTague has noted, the universities find themselves with aging facilities, obsolete equipment, and already alarming shortages of both faculty and students in many important fields.

In part, these problems simply reflect the fact that in the 1970's, in real terms, the support of university activities was essentially flat. In part, too, it reflects the fact that each year, the universities deferred the hard priority decisions and, not surprisingly, protected their most valuable asset, their people, at the cost of deferring maintenance and modernization and, in effect, mortgaging their futures against the hope that next year was going to bring a rosier financial picture. A decade and more of this has left us with a heavy deficit that we, as a nation, can ignore only at substantial peril.

Without increased support, it simply is not going to be possible for the universities to respond to the burgeoning demands they now face. Of the almost $100 billion that was expended on R&D nationally in 1984, only $8 billion found its way to the universities. We, as a Panel, feel that this is not appropriate for the demands that they face.

But increased support alone, as Dr. McTague has emphasized, isn't in itself the answer, although it is important. Rather, the time has come, we believe, to reexamine the entire relationship between the universities and the Federal Government and between the universities and the private sector. We emphasize in particular that the time has come for us to go back and view the support of university activities as an investment in the Nation's future rather than the procurement of specific goods and services.

Simply put, Mr. Chairman, we believe that unless we begin to take decisive action and start now, then, for the first time in our national history, the higher education enterprise that we pass on to our children and to our grandchildren will be less healthy, less able to respond to national needs, and less worthy of the great traditions of American education than the enterprise that we ourselves inherited.

In the report that is before you, "A Renewed Partnership," we have addressed these and other issues. We have made specific recommendations in several different areas. All are important. We urge your consideration of them. We also urge the consideration of all our fellow scientists and engineers. All of us are in this together and, together, we have the opportunity to make changes of enormous importance and benefit to our national future.

Let me emphasize, in case there be any misunderstanding, that our recommendations are interrelated and carefully designed to be implemented together. Indeed, partial or selective implementation, as has already been proposed in one case, can work substantial hardship and further damage on the universities.

What, then, are these areas of recommendation?

First of all, to maintain the strong science base that I think we all agree is essential to our national future, we recommend substantially greater investment in our centers of learning in the 1980's and 1990's than was available in the 1970's. We note that keeping pace with the overall national investment in R&D, a return to real growth in recent years that has been of critical im-

portance, would result in the doubling of the support to universities in 10 years. But this simply isn't enough. This will not enable the universities to restore and maintain the science base. We believe that even in times of budgetary constraints, the investment called for here is one that we simply must make.

We emphasize the importance of stability. In the absence of stability and predictability, important opportunities have been lost, scarce resources have been used ineffectively, and, most serious of all, some of the brightest young minds in each of our recent generations have been lost to science and engineering entirely and, indeed, to the many other areas of higher education that also are very important to our national future.

We are recommending that, because many of the major problems that are of the greatest national importance don't fit comfortably within the departmental structures of modern universities, important as those departmental structures are, that in order to bring the university, industry, and Federal Government resources to bear on broad interdisciplinary problems, we recommend a major initiative establishing university-based interdisciplinary research centers. Here, in part, we are building on the very great successes of the recent Engineering Research Center initiative.

One of the things that we have spent much of our time as a Panel examining is the question of university infrastructures. If we are going to maintain those on an ongoing basis, and if we are going to be able to assure that the universities are able to pursue their joint missions of research and education, we found it necessary to address not only the long term and what we would hope would be the steady-state situation, but also the fact that a period of catchup is essential to offset the effects of the 1970's.

To these ends, we recommended a 10-year, temporary facilities catchup fund that, in a great many ways, Mr. Chairman, is very similar to the one that you yourself have introduced in H.R. 2823; as a Panel, we would like to take this opportunity to compliment you on your leadership in bringing this important problem to public attention. We have one major point of difference, and that reflects our conviction that the research community is already significantly underfunded for the demands being made upon it, and, in consequence, we would urge—again, with full recognition of the difficulty involved, particularly in our present budgetary climate—that the catchup fund be incremental to the present level of research funding rather than a set-aside from within it.

Quite independently, Mr. Chairman, our Panel arrived at the same estimate as did you for the minimum facilities program that is required: $10 billion over 10 years with $5 billion from the Federal Government and $5 billion from non-Federal sources. We believe very strongly that in order to maintain excellence in this program, awards from the fund should be made on a 50–50 matching basis and on the basis of peer reviews in the scientific and technological communities involved.

With the infrastructure problems being addressed from such a catchup fund, we then recommend that the universities be assured an adequate cash-flow, in the steady state, through more realistic amortization of university facilities and equipment. We recommend, for example, that the useful lifetime of facilities be reduced

from 50 to 20 years and of equipment from 15 to somewhere between 5 and 10 years, depending upon the precise nature of the equipment involved. It is our belief that by doing so, we will more than offset the reduction in Federal funding that some universities will insure as a consequence of our further recommendation that the administrative component of indirect costs be fixed, for all universities, at the national average which is effectively 26 percent in direct costs. We cannot emphasize too strongly, however, the direct coupling between our amortization and administrative cost recommendations. Implementation of only the latter, as OMB has proposed, without the former, is not at all our recommendation.

This recommendation that we have made concerning administrative costs is made primarily to minimize the growing and unproductive controversy and friction concerning reimbursement of indirect costs. It is only representative of the many areas where we find that regulations, reporting requirements, and paperwork have been accreting beyond either utility or sense. We make a number of specific recommendations which we hope will cut through this morass. When some of the best of our young scientists tell us that they are spending 30 percent of their time, at ages when their creativity is at its peak, in required bureaucratic activity, we have more than begun to defeat our purposes.

Because we make unprecedented demands for leadership in a society like ours on that small group of most able and gifted young people, we believe it is essential that we identify these people early and that we provide them with the support and encouragement that will enable them to develop their gifts to the full. For that reason, we recommend that we accept as a national goal the support of the most able 1 percent of the young persons in each entering college class on full portable, merit-based scholarships during their 4 years of undergraduate study. We are convinced that the roughly $120 million per year that would be required to support such a program for scientists, mathematicians, and engineers would represent perhaps the wisest investment that any nation can make in its future.

We emphasize, of course, that this is certainly not intended and, indeed, it must not replace the critical need-based programs that have opened our universities to a whole generation of students who, for many reasons, would otherwise have been denied access.

We address in our Report a series of other recommendations to graduate fellowships, to midcareer and continuing education areas, as Mr. Packard has emphasized, which are of critical importance, particularly in the very rapidly moving fields of technology that our scientists and engineers are involved with at the present time.

It is important, too, in considering this overall problem to recognize the vital role that State and local governments, as well as private philanthropy play in building and maintaining our higher education enterprise. Their initial investments develop the structure and programs that make universities and colleges competitive for Federal support in the first place, and they provide the resources that allow these institutions to preserve their autonomy and their diversity. We believe that this kind of support is an element that is going to be of critical importance in the years ahead.

There is a vital role for the State and local governments and for private philanthropy.

Finally, let me echo Mr. Packard's comment that strong university-Government-industry partnerships are really fundamental to meeting our goals in economic competitiveness, national security, and so many other areas of national importance. Very substantial progress has been made in recent years in building new bridges between universities and individual corporations. We believe that the Federal Government can play a very important catalytic role in fostering these interactions.

We make specific recommendations concerning the organization of the Tax Code and specifically recommend a 25-percent nonincremental tax credit for industrial funding of university-based research as well as for industry-supported maintenance and servicing of university equipment. This latter is important, because, time and again, we have heard of universities which have had industrially-donated equipment at the frontiers of modern science gathering dust because they simply were unable to afford to maintain and service it. This kind of instrumentation and equipment is extremely valuable and important. For that reason, we recommend the establishment of a tax deduction equal to its full market value.

We think, also, that it is important to emphasize that although there are a great many opportunities for fruitful cooperation involving industry and the universities, and it is going to be very important for us to develop these, it is important, given the fundamental uncertainty as to the timing and the identification of the ultimate beneficiary of any particular piece of basic research, to understand that industry can't be expected to undertake major expansion of its basic research activities. As we emphasize repeatedly in our Report, the maintenance of the national science base has been and remains a Federal trust.

Mr. Chairman, in our Report, we have focused on the natural sciences and engineering; but as Mr. Packard noted earlier, we can't emphasize too strongly that the health of the entire spectrum of American higher education—from chemistry to computer science to the classics—is important to our national future. In a society of ever-increasing technological sophistication, we simply can't afford citizens who can't at least appreciate the central issues involved; no more can we afford generations of scientists and engineers unable to appreciate the economic and social consequences of their work or the underpinning of philosophic and moral judgments on which it rests.

I noted at the outset of my testimony, as did Dr. McTague and Mr. Packard, that only with increased support can our universities hope to respond to the growing demands being made upon them. Let me then close by noting that even with that support, hard choices lie ahead for both the colleges and universities. It is not going to be possible in the short term to accomplish all those things that would be in the national interest. It may well be impossible to accomplish all of them even in the long term. But it will be the responsibility of each university and college to manage its own destiny—to make the very difficult tradeoffs among faculties, facilities, and programs necessary to maintain its institutional health

and vitality within whatever level of external support it may find itself constrained to operate.

We are confident, Mr. Chairman, that if the recommendations in our Report can be implemented, the universities can and will respond enthusiastically to the challenges that lie ahead. Working together, and with generous support from the Congress and from the U.S. taxpayer, we have built, in this country, a science and technology enterprise that has been the envy of the world. With your help, we are confident that it will be possible to maintain the leadership in these areas that is essential to our well-being in a rapidly changing, highly competitive, and increasingly technological world.

Mr. Chairman, I would be happy to join in answering your questions.

[The prepared statement of Dr. Bromley follows:]

STATEMENT OF

DR. D. ALLAN BROMLEY
HENRY FORD II PROFESSOR OF PHYSICS
YALE UNIVERSITY

Before the

COMMITTEE ON SCIENCE AND TECHNOLOGY
SCIENCE POLICY TASK FORCE

UNITED STATES HOUSE OF REPRESENTATIVES

MAY 15, 1986

Testimony of D. Allan Bromley

before the

House Committee on Science and Technology

99th Congress

May 15, 1986

Mr. Chairman, I very much appreciate this opportunity to appear before you and The Science Policy Task Force on this important topic. I am D. Allan Bromley; I hold the Henry Ford II Chair of Physics at Yale University and am currently President of the International Union of Pure and Applied Physics.

Today I should like to touch briefly on the major findings and recommendations that have emerged from our White House Science Council study on the Health of U.S. Colleges and Universities. Dr. McTague and Mr. Packard have already given you an overview of our activities during this study. With your permission, Mr. Chairman, I should like to submit, for the record, a copy of our Report entitled A Renewed Partnership, which includes detailed listings of our findings and recommendations.

Several findings stand clear:

- Because of our long-held belief, in this country, that higher education in science and engineering and basic science and engineering themselves are inextricably linked and symbiotic, we are uniquely dependent on our universities for both the new knowledge and the young minds trained to use it effectively. In consequence, support of university-based research has both an immediate payoff--the

young scientists and engineers--and a longer-range one--the fruits of the new fundamental and applied knowledge that result from that research.

- Reflecting the unprecedented speed and scope of the changes taking place in modern science and technology--world wide--the demands being made upon our universities and colleges have never been greater as our nation responds to challenges in the international marketplace, in national security, and in securing a better quality of life for all our citizens.

- But just at a time when much is expected of them, after something like a decade of relative neglect--and, indeed, of less than optimum management of their own affairs--the universities find themselves with aging facilities, obsolete equipment and already alarming shortages of both faculty and students in many important fields.

  In part these problems simply reflect the fact that federal support for university-based activities was essentially flat, in constant dollars, during the 1970's; but in part too they reflect the fact that each year the universities deferred the hard priority decisions and, not surprisingly, protected their most valuable asset, their people, at the cost of deferring maintenance and modernization and, in effect, mortgaged

their futures against the hope that next year would bring a rosier financial picture. A decade and more of this has left us with a heavy deficit that we, as a nation, can ignore only at our peril.

- Without increased support it will simply not be possible for the universities to respond to the current burgeoning demands. Of the almost $100 billion expended nationally in 1984 for research and development, it bears noting that only about $8 billion found its way to universities. But increased support alone is certainly not the answer; rather, the time has come, as Dr. McTague has suggested, to reexamine the entire relationship between the universities and the federal government and between the universities and the private sector. The time has come to return to an earlier view of the support of university activities as reflecting an investment in the national future rather than the procurement of necessary goods and services.

- Simply put, unless we take decisive action now, for the first time in our national history the higher education enterprise that we pass on to our children and grandchildren will be less healthy, less able to respond to national needs, and less worthy of the great traditions of American education than the enterprise that we ourselves inherited.

In the report now before you--A Renewed Partnership--we have addressed these and other related issues, and, after extended discussions among ourselves and with representatives of a great many institutions, we have made specific recommendations in several different areas. All are important, and we urge not only your attention and action, but also that of all of our fellow scientists and engineers. All of us are involved, and together we have the opportunity to make changes of enormous importance and benefit to our national future.

And lest there be any misunderstanding, let me emphasize that our recommendations are interrelated and carefully designed to be implemented together. Indeed, partial or selective implementation--as has already been proposed--could work substantial hardship and further damage on the universities.

What then are our major areas of recommedation?

- To maintain the strong science base essential to our national future, we have recommended substantially greater investment in our centers of learning in the 1980s and 1990s than was available in the 1970s. Keeping pace with the overall national investment in R&D in recent years--a return to real growth that has been of critical importance--would result in doubling support to the universities in 10 years; but this is not enough to restore and maintain the science base. Even in times of severe budgetary constraints, we are

convinced that the investment called for here is one we must make.

Of equal importance with the actual level of funding is the stabilization of federal support to permit more effective use of both financial and human resources. The most ambitious research often requires long lead times for preparation and development. And research groups, by their very nature are exceedingly fragile; once disbanded they can almost never be reassembled. In the absence of stability and predictability, important opportunities have been lost, scarce resources have been used ineffectively and most serious of all, some of the brightest young minds in each of our recent generations have been lost to science and engineering entirely.

To bring the unique resources of all three of the universities, industry and the federal government to bear on broad, interdisciplinary problems of pressing national importance, we have also recommended a major initiative to establish university based, interdisciplinary research centers. Here, in part, we build upon the very real successes of the recent Engineering Research Center initiative.

- To enable the universities to rebuild their infrastructures and maintain them on an ongoing basis and to assure that the universities are able to pursue their joint missions of research and education effectively, we have

found it necessary to address not only the long-term steady state situation, but also the fact that a period of catch-up is essential to offset the effects of the decade of the 1970s.

To these ends, we have recommended a 10-year temporary facilities catch-up fund that in a great many respects resembles the one that you, Mr. Chairman, have introduced in HR 2823; we would particularly wish to compliment you, Mr. Chairman, on your leadership in focusing attention on this vital problem. Our major point of difference reflects our conviction that the research community is already significantly underfunded for the demands being made upon it, and in consequence, we would urge--again, with full recognition of the difficulty involved, particularly in our present budgetary climate--that the catch-up fund be incremental to the present level of research funding rather than a set-aside from within it.

Quite independently, Mr. Chairman, our Panel arrived at the same estimate as did you for the minimum facilites program: $10 billion dollars over ten years, and we, too, recommend that half of this come from the federal government and half from non-federal sources. We believe very strongly that to foster excellence, all awards from the fund should be made on a 50/50 matching basis and on the basis of peer reviews in the scientific and technological communities involved.

With infrastructure catch-up problems being addressed from such a fund, we then recommend that the universities be assured an adequate cash flow, in the steady state, through more realistic amortization of university facilities and equipment. We recommend that the useful lifetime of facilities be reduced from 50 to 20 years and of equipment from 15 to between 5 and 10 years depending upon the precise nature of the equipment involved. It is our belief that this more realistic amortization will more than offset the reduction in federal funding that some universities will incur as a consequence of our recommendation that the administrative component of indirect costs be fixed, for all universities, at the national average-effectively 26% of direct costs. We cannot emphasize too strongly, however, the direct coupling between our amortization and administrative cost recommendations. Implementation of only the latter, as OMB has proposed, without the former, is not at all our recommendation.

- Our recommendation concerning administrative costs, just noted, is made primarily to minimize growing and unproductive controversy and friction concerning reimbursement of indirect costs. It, however, is only representative of the many areas where we find that regulations, reporting requirements and paperwork have been accreting beyond either utility or sense. We make a number of specific recommendations designed to cut through this morass.

When some of our most able young scientist and engineers tell us of spending more than 30% of their time--at ages when their creativity is at its peak--in required bureaucratic activity, we have more than begun to defeat our own purposes.

- Because we make unprecendented demands for leadership in a society like ours on that small, most able and gifted group in each generation, it is essential that we identify its members early and provide them with the support and encouragement that will enable them to develop their gifts to the full. It is our recommendation that we accept as a national goal the support of the most able 1% of young persons in each entering college class on full portable, merit-based scholarships during their four years of undergraduate study. We are convinced that the roughly $120 million that would be required each year to support such a program for scientists, mathematicians and engineers would represent perhaps the wisest investment that any nation could make in its own future.

  It is essential that we emphasize that this recommended scholarship program is not intended to--and indeed must not--replace those very important need-based programs which have opened the nation's colleges and universities to a great many students who, for various reasons, would otherwise have been denied access. Such students have made our colleges and universities vastly more interesting

and stimulating places and are already playing vitally important roles throughout our society.

We address other related recommendations in our Report to the question of graduate fellowships and the areas of mid-career and continuing education-areas of crucial and special importance to scientists and engineers in very rapidly moving fields.

- It is essential that we also recognize the vital role played by both state and local government as well as by private philanthropy in building and maintaining our higher education enterprise. Their initial investments develop the structure and programs that make universities and colleges competitive for federal support in the first instance, and they provide the resources whereby these institutions reserve their autonomy and diversity. Such support is a major element of the shared responsibility that typifies our present university-federal government partnership; it is an element that will be critically important in the years ahead.

- Strong university-government-industry partnerships are fundamental to meeting our goals in economic competitiveness, national security, agriculture, health, and in improving the quality of life of our citizens. Substantial progress has already been made in recent years in building bridges of shared interests between universities and individual corporations. The Panel believes that the

federal government can play an important catalytic role in fostering such interactions. In any reorganization of the federal tax code, for example, we recommend that the importance of these interactions be recognized. We recommend that a 25% nonincremental tax credit should be established for industrial funding of university based research as well as for industry-supported maintenance and servicing of university equipment. We have learned of not infrequent instances where industrially-donated instrumentation and equipment has gathered dust because the recipient university simply could not afford to maintain and service it. Such industrially-donated instrumentation and equipment is extremely valuable and important and we recommend establishment of a tax deduction equal to its full market value.

While there remain many opportunities for very fruitful university-industry cooperation, it is important to emphasize the very real limits to industrial interest in, and support for, university-based activities. Given the fundamental uncertainty as to the timing, and identification of the ultimate beneficiary, of any piece of truly basic research it is understandable that industry cannot be expected to undertake major expansion of its basic research activity. As we emphasize repeatedly in our Report the maintenance of the national science and technology base has been, and remains, a federal trust.

Mr. Chairman, in our Report we have focused upon the natural sciences and engineering; but we cannot emphasize too strongly that the health of the entire spectrum of American higher education--from chemistry to computer science, and to the classics--is important to our national future. In a society of ever-increasing technological sophistication we cannot afford citizens who cannot at least appreciate the central issues involved; no more can we afford generations of scientists and engineers unable to appreciate the economic and social consequences of their work nor the underpinning of philosophic and moral judgements on which it rests.

I noted at the outset of my testimony, as did Dr. McTague and Mr. Packard, that only with increased support could our colleges and universities hope to respond to the growing demands being made upon them. Let me close by noting that even with that support, hard choices lie ahead for them. It will not be possible to accomplish all those things that would be in the national interest in the near future; it may well be impossible to accomplish all of them even in the long term. But it will be the responsibility of each university and college to manage its own destiny--to make the difficult trade-offs among faculties, facilities and programs necessary to maintain its institutional health and vitality within whatever level of external support it may find itself constrained to operate.

We are confident, however, Mr. Chairman, that if the recommendations in our Report can be implemented, the universities can, and will, respond enthusiastically to the challenges that lie ahead. Working together, and with generous support from the Congress and

from the U.S. taxpayer, we have built, in this country, a science and technology enterprise that has been the envy of the world. With your help, we are confident that it will be possible to maintain the leadership in these areas that is essential to our well-being in a rapidly changing, highly competitive, and increasingly technological world.

Mr. Chairman and members of the Committee, I much appreciate having the oportunity to appear before you this morning and shall be happy to respond to your questions at the appropriate time.

Mr. PACKARD. If I may, I would like to make just a comment or two.

Mr. FUQUA. Yes, sir.

Mr. PACKARD. In the first place, I wanted to point out that, as you can judge from Professor Bromley's comments, he did most of the work on this Commission and this Report, and he really should have been the Chairman. I wanted to make the point that he is really responsible for a great deal of work here.

As you can judge, I had a great interest in it, and I was pleased to participate. I had a few other things to do in the interim, as some of you know, but in any case, I feel very grateful to Professor Bromley and wanted you all to know that he deserves really the credit for the Report.

Dr. BROMLEY. We are all in it together.

Mr. PACKARD. I wanted to make one other point that comes out of my own experience. That is the fact that research is becoming much more costly today than it has been in the past. Again, just to give examples out of my own experience, we started our company with a total investment of $500. We could buy our equipment and everything else we needed to start our business in those days. Today——

Mr. FUQUA. It wouldn't even buy the license to open the doors.

Mr. PACKARD. You can't start without $1 million or several million dollars, and that is just a measure of how far this whole thing has gone. It is simply because, particularly in the electronics field, as you know, these large-scale integrated circuits where you are putting up to 1 million active elements on a little piece of silicon one-quarter of an inch square, you can't do that with a pair of pliers and a screwdriver. You have to have very precise equipment even to look at what is going on and know what is going on, and it is extremely expensive.

One of the things that comes out in our Report is that there is an increasing number of foreign students enrolled in our graduate schools in science and technology. We think that number is not too large. The fact is simply there are not enough U.S. students who are going into these graduate programs. One of the reasons is that they have opportunities to take jobs in industry where they have better facilities and better equipment to do the research than they have in the universities, so the lack of this equipment in universities is a very serious disincentive for these young people to continue their education as they should.

This is also true to some extent of the faculty. Our Report says that there is something like a 10-percent shortage of faculty overall. In some disciplines, computer sciences and electronics, some universities are reporting that 50 percent of their positions are open and they are unable to fill them. Here again it is because the universities don't have research equipment for these people to work with which is comparable to that which they can work with in industry.

So, this lack of appropriate equipment in the universities is a very serious disincentive to keeping the faculty there and to encouraging more students from the United States to continue their studies in this field.

That is one point I simply wanted to add before you go to questions, and I would be pleased to respond to questions at this time.

PANEL DISCUSSION

Mr. FUQUA. Thank you, Mr. Packard. Let me first start off by commending Dr. Keyworth for his foresight in forming this group and, second, to also commend him for his foresight in having such distinguished people chair it and lead the group, because it is an area that I think is probably of the most critical that we have facing the future of the country. As Mr. Packard pointed out, there is an increasing need in the time we live in today for a continuing education after you graduate from college, to come back. Industry recognizes that, and I think we all recognize that. To not do that, we are mortgaging our future, and that is something I think, as a nation, we do not need to do.

You touch on some areas that have been of great concern to this committee. We have tried to address them in some of the legislation. It is not chiseled in granite. We have tried to look at the practicalities of the real world that we live in today, but, again, it is not chiseled in granite, and it is subject to constructive modification in any way that will help answer the problem that we are faced with.

I am interested, Mr. Packard, or all three of you, for that matter, if looking into the future—and that is what we are trying to do in this study, trying to look at the next 40 years and into the next century—if we are going to need an increased number of major research institutions. You mentioned Stanford and you mentioned several in your comments, Mr. Packard. Are we going to need more or the same number or less in the future as we look into the next century or probably the next 40 or 50 years?

Mr. PACKARD. Dr. Bromley would probably be better able to answer that question. In my view, I don't think there is a need for many more institutions. I think the main problem is how to enable those institutions which are already in place to do a better job.

Now, there is one aspect of this that is important. Professor Bromley mentioned it. There is a need for more interdisciplinary research where universities get together with a research center and this provides an exchange of knowledge among the people involved.

We studied the Federal laboratories a few years ago, and we think there is an opportunity for a better relationship between the Federal laboratories and the universities. So, I would think, all in all, there is not any need to establish more new universities. I think if we utilize the ones that are now available, we could handle the job very well.

Mr. FUQUA. Do you think the number of people who would be requiring this continuing education and the number of graduate students, as the population increases in the country, the present number of these research institutions would be able to absorb what may or may not—maybe there is not going to be an increasing number of people going into that.

Dr. BROMLEY. Mr. Chairman, I would like to answer in two parts. First of all, I agree with what Mr. Packard has said. I don't believe that we need new institutions. I believe that the fundamental crite-

rion that we should be focusing on is the development of excellence in science and engineering. It may well be that in order to make available to students in various parts of our country that we will have to give some emphasis to improving the level of activity in certain institutions, but I quite agree that I see no need at all for increasing the number of institutions.

On the second point, that of midcareer training, it seems to me that there is an opportunity here for a number of universities that perhaps will not find it possible to compete for the smaller group of students that will be coming forward in the next generation in the normal undergraduate programs, there is a role here for universities that move aggressively now to develop attractive midcareer and continuing education programs because they require somewhat different structures, somewhat different faculties to be really effective.

I think that we will see in the country, we must see in the country, over the next number of years, a real push to develop excellent programs in this latter area that you have raised. It is a very important one.

Mr. PACKARD. Let me answer that question specifically, because we have had a lot of experience in that very thing. One of the first things we did with Stanford is to arrange a program with the head of the engineering department there so we could hire graduates from other universities around the country and assure that they could get into the graduate program at Stanford.

The way we did this was to simply this way: Professor Terman said "Look, the tuition covers about half of the cost of the graduate work. If the company will put up the other half, we will add additional places, and you can have those additional places for the people you employ." Obviously, this was a tremendous lever for us for hiring young people from all the way across the country and making sure they could get some additional education.

When this program first started, we let them have time off from work to attend classes. That didn't work too well, so we let them have a whole semester off.

In the meantime, we have developed with Stanford and we have developed also with the University of Colorado in Colorado Springs, and other places in Colorado, a closed-circuit television program whereby our employees can attend class right in the plant and have closed-circuit television with microphones so they can ask questions. There was a great deal of concern by the faculty as to whether this would work. After it had gone on for a while, it turned out that our employees got better grades than the people who actually attended class. So, that whole thing has been thoroughly demonstrated.

All this is to say that there are a whole lot of modern communication techniques that can be used extensively. This means, you see, that a larger number of students can participate in the classes that the professors are already undertaking. I don't see any problem in expanding this and meeting this need. It is going to take some ingenuity and some imagination, but I think it can be supported by industry.

I just wanted to bring that example out, because I have seen some very interesting progress made in that particular area.

Mr. FUQUA. John, would you care to comment?

Dr. MCTAGUE. I would just like to discuss a parallel track, and that is in this country, we enjoy a standard of living that is very high indeed, and we want to pass on to our children at least that opportunity. This requires that in the commercial sector we aim at the highest possible value added. That means being at the forefront of technology.

Likewise, in our national defense, we rely very heavily on weapons systems that give us leverage from technology when we are outnumbered by 3 to 1 in terms of actual troops out in the field. So, we must have high value added.

That means that in the future, we must attract and retain in science and technology an increasing fraction of the best talent in the country. It doesn't necessarily mean large increases in overall numbers. It means that we must attract quality, as Professor Bromley was emphasizing.

I don't think we can plan in numbers of students any more than we can figure out the future of the price of oil, et cetera, what we actually need, but students do indeed respond to perceived opportunities. We must make those opportunities more attractive to them in terms, as Mr. Packard was pointing out, of equipment, in terms of stipends, in terms of increased cooperation between Government, universities, and industry, particularly university and industry along the lines that Mr. Packard was pointing out. If students perceive these things, a larger fraction of the talent will indeed go along the path that will be of highest value added for our country.

Along these lines, I want to note that I recently spent a few weeks in Southeast Asia. In particular, I want to note to you my experience in Thailand. Thailand has a significantly lower standard of living than the United States, but it is rising very rapidly. They recognize the importance of education over there, and they send a lot of students to the United States even though it is very costly to them, much more costly in terms of their own resources than it is for Americans.

Most of those students return—in excess of 90 percent of them return to Thailand and contribute to their own increase in science and technology which I think is good, in fact, for us because we must have a marketplace out there which can buy what we are making.

But the thing that I want to note to you is that I visited many scientific and technological institutions over there. The majority of the scientists there are women. More than 50 percent are women. We are really missing out on a tremendous resource in this country.

Mr. FUQUA. How do they account for that when that is one of the things we have been looking at during this study, is now to involve more women and minorities, and there is evidence in some of the studies, particularly the OTA study they did for this task force, that women are going into professional jobs such as medicine and law, but not many are going into engineering or science fields, excluding medicine from science. How would you ascribe the differences? That is a little off the subject we are talking about, but it is something that has been of interest to the task force.

Dr. McTAGUE. I think role models have a lot to do with it. It is the chicken and the egg business. Until you have some, you are not going to get more. My own experience in 12 years as a professor at UCLA was that there was an enormous change in the retention of female graduate students in my own department once we had one tenured woman faculty member.

Dr. BROMLEY. If I could, Mr. Chairman, just add to this last question, one of the real problems we address, I think, is that in high schools in this country, it takes a singularly determined woman to overcome the hurdles that are still placed in their way. There is still the myth that women shouldn't get involved in anything mathematical. This continues. We work on it, but we have not succeeded very well. I think that until we have more women as role models, and until we somehow can go back into the high schools and change this idea about the hard sciences and mathematics and can improve the quality of the counseling that young people are getting in high schools in this Nation, we are going to continue to have these problems.

Mr. PACKARD. Let me just make a comment about that. I think we are making some real progress in this area. We have tried over the years in our company to attract more women. When we were involved in the field of instrumentation, it was not a very attractive or interesting thing for women. Since we have been involved in computers and data products, we find that there are just a lot of very bright young women that are coming into the company now. This is true of other companies as well.

I just visited one of our field offices last week in the State of Washington, the only field office in the whole country that had met their quota last year, and a young woman was in charge of the whole program. And she was doing a better job than anybody else in the whole company. So, we are making some progress in this area.

Mr. FUQUA. That is good.

To get back on the subject of the meeting this morning, I notice that you mentioned that in the facilities area that it should be on a peer review process. I am wondering who makes up the peer review. Normally, if you are talking about a physics proposal or an engineering proposal or a chemistry proposal, you have chemists or people of that discipline. Who makes this up, civil engineers, architects, or the president of the university or the vice president for administration or whoever is——

Mr. BROWN. Or Members of Congress.

Mr. FUQUA. Or Members of Congress or the mayor or whatever. Who makes up that peer review that determines whether you need this type of facility there?

Dr. BROMLEY. We recognize, Mr. Chairman, that this is a singularly thorny problem. From our point of view, however, we believe that the idea that has served us so well over the years in this country of having people who are knowledgeable in the general area in which the expenditure is about to be made have an input to the decision. We recognize that in many of these cases, the final decision will not be made purely on the basis of the peer review evaluation, but we believe that that is critical and necessary, if you will, but not sufficient, input to the final decision. That is the way in

which we have maintained in this country a quality standard that undergirds the strength we have in science and technology.

Mr. FUQUA. Would it be something like an accreditation panel that determines that you need better facilities in order to continue?

Dr. BROMLEY. There are several questions, Mr. Chairman. I think, first of all, that you need, if you are going to build a building in a particular science, let us say, what you can get from the peer review evaluation is some input as to the quality of the people who will subsequently use it if it is placed in a certain place, the need for it within the science—there are other needs that you will want to address from other angles with other people—but you can get an evaluation of the quality of the people, the quality of the students, and the quality of the science, in large measure, that you might expect to come out of it.

Mr. PACKARD. Mr. Chairman, I think maybe we ought to call a spade a spade when we are talking about this subject. One of the problems I think we are really concerned about is the fact that sometimes a group of university people come in here to the Congress and put on a big presentation and get a lot of money for a particular university without having that be effectively reviewed by some independent people who, hopefully, can evaluate whether that really is the place where the money should be spent or not. So, really, what we are saying is that we hope that the Congress, in considering these matters, will not yield completely to the pressures from their constituents but will look at the importance of trying to allocate our resources in the right way.

Mr. FUQUA. You are really saying, I think, that the allocation of the funding should be based on merit rather than pork barrel.

Mr. PACKARD. That is right. And you can get some evaluations. The National Academy of Sciences can do it. You can get a panel of university people. We understand that this is a democratic process and it can't be controlled completely, but I think we are suggesting that a little more attention ought to be paid to that kind of a problem.

Mr. FUQUA. There was an interesting article in the *Washington Post* this morning about what is about to happen in the other body. Of course, it is extremely difficult to take politics out of politics. I think it is further pointing to the dire need that we enact some type of legislation, because the pressure is continuing to build and build and build to take care of some of these critical needs that we have throughout the country. It is being done on a basis other than necessarily probably merit or some type of critical evaluation of that. So, I think it is further pointing to the need for something along the lines of your Report or the legislation that is before this committee at this time.

Mr. Brown.

Mr. BROWN. Thank you, Mr. Chairman.

May I reiterate what the chairman has already said about the importance of your study and the appreciate that we have for the work that has gone into it. Sometimes we are a little critical on a political basis of administration initiatives, but I think from the beginning, and I attribute a lot of it to, first, Dr. Keyworth's leadership role and, second, the fact that he was able to tap a number of people, including you, Mr. Packard, fairly often for help on things

like the Federal laboratory study and the industrial competitiveness study and so on, that we have a series of excellent reports of which I think this is perhaps the best in terms of policy steps that need to be taken.

I would almost be willing to assert that, as far as this task force is concerned, we could almost say amen to what you have done and include it in our report as an example of the things that need to be done from a policy standpoint to get us back on the track of achieving the national excellence and the national superiority that we all want.

Having said that, I don't think we have solved all of the problems, and I am sure you recognize that. Within the administration, you have had this conflict on almost all of these reports that have indicated a greater need for Federal leadership, policy leadership, and an activist role, you might say. You have tensions within the administration which tend to move it in the other direction to, in effect, abdicate responsibilities in certain areas as being more appropriate to the State or local government, to local educational institutions, to the private sector, most of which is probably true, except insofar as to what you have recognized. You can't abdicate leadership. There has to be some form of Federal leadership here.

Let me make one or two points and ask you to comment on them. In your statement, Mr. Packard, you said that the Panel supported the Government's present policy of channeling its R&D knowledge toward basic scientific research and away from commercialization projects that are more properly the province of private industry. I couldn't agree more wholeheartedly with you, but you beg the question. What do you do in between the basic research and the commercialization? I am talking here of targeted research, the technology base development, the proof of concept stage. These are the areas where the controversy arises.

Mr. PACKARD. Well, I think clearly, as we have indicated, it is not a clear black and white matter that all the research should be done in one place and all the commercialization should be done in another place. I think there is an increasing recognition that industry has been a great beneficiary of the work that is done in universities, and industry is indeed increasing its support of universities.

Unfortunately, a very large part of our industrial community does not recognize the importance of research to the extent they should and that, in my opinion, is why some of our industries have fallen behind. A lot of us are trying to encourage these industries to undertake more of this research. It comes partly from some unfortunate pressures, the pressure of trying to show a better profit every month, as a deterrent to investing in some long-term basic research. I wish there were some way to deal with that.

Mr. BROWN. Let me interrupt you here, Mr. Packard. I don't think we argue about long-term basic research. That is a Federal role, and the administration agrees with that as a Federal role. What about long-term technology base development? I am not talking about fundamental research. I am talking about developing a technological base which goes beyond the scope of what any one private enterprise can handle. Let me give you the aeronautics research report of the administration as a primary example.

Mr. PACKARD. Well, the space program, of course, is an example of that. It cannot be undertaken by industry alone and, of course, defense is another very important example where defense not only supports basic research but supports everything clear on up to product development.

There are indeed projects that are too large for any one company to take on. I think it is encouraging that you are seeing some more cooperative areas between industry. One of the things that has been a deterrent to that has been Federal antitrust policies which have discouraged these kinds of cooperation. If you compare what is done in this country with what is done in Japan, for example, Japan has a very strong government-supported program where industry works together in areas that they think are going to be of importance in the long term. I think we should endeavor to increase that kind of activity in this country.

Mr. BROWN. I am very glad to hear you say that. I am not trying to be critical, Mr. Packard. I am trying to clarify certain areas which I think are going to be the focus of the political debate.

Mr. PACKARD. Well, it is a fact we are facing a new problem now, and we have to find some new ways to deal with it.

Dr. MCTAGUE. Might I make a few remarks? I certainly agree with you, Congressman, that a major difficulty we have is in bridging from our excellent basic research foundation to rapid and effective implementation in terms of product. You have identified an area that we haven't addressed as effectively as we must because the competition is addressing it.

Mr. BROWN. You didn't want to get into too many fights at one time, I will bet.

Dr. MCTAGUE. With respect to technology base, I think you have picked an area in which we probably are doing something fairly effective, and that is in aeronautics. There, there is an acknowledge confluence of interest between the Government as a consumer of technology and industry as a creator of commercial technology. Certainly, the aeronautics field and the aerospace field in general has been one of the shining lights of this country.

We, in the aeronautics area, within the Office of Science and Technology Policy, have been addressing this issue for quite some time. You noted the aeronautics research report which has come out and has had significant impacts, for example, on the President's initiative in the national aerospace plane technology thrust.

Mr. BROWN. I regard it as a bible, Dr. McTague. It is an excellent job.

Dr. MCTAGUE. Thank you. If that is the Old Testament, the New Testament is coming out in October, by the way.

But the other issue is how do we get more effective technology transfer, and I think the aeronautics area is an indication. It involves partnerships, mutual interests, people-to-people relationships. It is no accident that the title of these gentlemen's report is "A Renewed Partnership." Effective interactions, such as Mr. Packard has discussed, between industry and universities are worth a heck of a lot more than another Federal program.

Dr. BROMLEY. We would certainly agree, Mr. Brown, that this is a critically important area. We felt that the success that has been achieved thus far in the Engineering Research Centers at least

moves in this direction of bringing industry together with the university. We now have 11 of those, 6 that have been in place, 5 new ones, and it is specifically for this reason that we make the major recommendation in this document that we feel that the time has come to establish a real initiative of establishing interdisciplinary research centers at universities to bring together the strength that the university has with industry with some catalytic help from the State and Federal Governments to address some of these very important transfer problems.

Mr. BROWN. I should make it clear when I mention the various links in this important chain from basic research to commercialization that I am not suggesting the Federal Government be responsible for any particular one of these things. I am suggesting that the Federal Government has to be aware of the problem and the necessity to create the linkages and to provide the atmosphere or the leadership in which it can be done. The aeronautics is a classic example of how this can be done and done well, but we also need this, as we have been debating recently, in advanced satellite communications, and we need it in a number of other areas.

Mr. FUQUA. Energy.

Mr. BROWN. Energy—where the record hasn't been so good.

For 10 years, we have been making slow progress toward recognizing the importance of the things that you have in your Report here. You didn't create this out of the blue, you know. We have been losing competitive position. We have wondered what to do, and we were beginning to see the shape, and you have formulated it very well, but we don't have consistency.

We in this committee recommended these interdisciplinary research centers 8 years ago, at least, and enacted them into law in the Stevenson-Wydler Act and with very little success. Now that you have blessed this, we are going to go full steam ahead.

One of the problems with our national policy is this lack of consistency which I think all of you are aware of. If you look at the record, to take an invidious example, of our competition with the Soviets in the arms field or in certain other fields, their strength is consistency. They don't go into a crash program for 5 years and then forget it. Their support for militarization has been at a steady 2- to 3-percent increase per year for the last 25 years. We have gone up and down like a yo-yo, and we would be much better off if we didn't go up and down like a yo-yo.

Let's go to another point.

Mr. FUQUA. Mr. Brown, Mr. Packard has an appointment at 11. If you have another question for him, maybe he can take one more or something.

Mr. PACKARD. I have a few minutes.

Mr. BROWN. OK.

There is an interesting movement in your Report, interesting and important one, which points to the need for stability in research funding, getting away from this 30 percent of our researchers' time being spent on annual grant applications. Of course, we have had a marvelously successful research program for 100 years in agriculture which has done this, but it is not without its weaknesses.

What we see in nonagricultural research in the NIH system—and you are recommending it for others—is greater stability, less time spent in grant preparation, maintain the integrity of the peer review process. In agriculture, we are moving in the opposite direction, away from formula grants to institutions toward competitive peer-reviewed research. In other words, both systems have their weaknesses, and they are moving toward a central common concept of what creates excellence.

I am fascinated by this fact that we are able to change our institutions if we keep in mind the overriding purpose for which these institutions have been created. I am sure that occurred to the members of the Panel.

Mr. PACKARD. All in all, I think that the record of Federal support of research has been pretty good. It has done a lot of great things for the country, and we can find some things that need to be corrected, and it is important that we do keep it in the forefront, but we don't mean to imply by any means that it hasn't been important. In agriculture, health, defense, and all of these things, we have made a lot of progress.

Our only point is we are not doing as well as we should do.

Mr. BROWN. Well, you have made a great contribution to helping us improve. It is my personal hope that the Members of Congress can all read this Report and we can get our act together and, likewise, the executive branch can get its act together better in a cooperative mode here.

I won't pester you with some of the other questions that I have here.

Mr. PACKARD. Mr. Chairman, if you would excuse me, I would appreciate it very much.

Mr. FUQUA. Yes. Thank you very much, Mr. Packard, for joining us this morning.

Mr. BROWN. I don't know how much longer you want to go on.

Mr. FUQUA. We can go on 5 minutes or so. We will have to give up the room.

Mr. BROWN. All right.

Dr. McTague, you made a significant insertion on page 2 of your statement in which you were pointing out the emphasis of the administration on greater support for basic research and less support for applied and technology development. But the insertion that you made was to point out that this is in the nondefense sector, because just the opposite is taking place in the defense sector. The percentage of the defense R&D dollar going to basic research has been declining. The reasons are obvious. It is expensive to go through the process of technology development for expensive military systems. So, that is where most of the money goes.

Do you think there is a problem there? Do you think that because now 75 percent of our total R&D dollars is defense and a large part of that is technology oriented that we may be shortchanging in the defense sector the importance of a more solid basic research? We will say not only basic but targeted basic research. Are we shortchanging that in favor of rapid development of high technology systems which, unfortunately, become obsolete very quickly and by inappropriate balance, we may be building up some problems for the future?

Dr. McTAGUE. Yes, sir, I do. I think the overall balance at present in defense R&D funding is not the most effective that it could be. The Defense Department is the major consumer in this country of high technology. It is also the single major consumer of scientific and engineering talent. Approximately one-sixth of all the scientists and engineers in the United States work on problems of national security.

Beginning in the Carter administration, there was a thrust to modernize significantly our weapons systems which has skewed what we view as the R&D budget into what is shorter and shorter term. But the figures commonly presented perhaps are misleading, and that is what is called the R&D budget in the Defense Department—for short, is called the R&D budget—is not the R&D budget. It is RDT&E [research, development, testing, and evaluation]. Indeed, the lion's share of RDT&E is T&E which is the share which has increased most rapidly because several of these weapons systems are coming on line now.

However, along the way, we have not made the increased investment necessary for assuring the future health, 20 years out, 10 years out, and for assuring the stream of talent that is necessary in this area. We are trying to do some things in that area. For example, the Congress this past year voted for the DOD University Research Initiative, which I think is a major thrust toward getting the Department of Defense back into the notion of the importance of investment in basic knowledge and in terms of university talent.

It is not enough, but it is a beginning. Much of it involves getting people who are aware of the short-term importance of modernizing our forces who also realize that it is in the national interest to not neglect the longer term.

Mr. BROWN. Well, I am bringing up the question of balance with the defense budget, because I have been deeply disturbed lately about what I have learned about Soviet R&D, again, their consistent support for the long-range R&D. I am also concerned, of course, and have said so frequently, about the appropriate balance between the military and the civilian and what it does to our overall strength as a nation in terms of the pressures on scarce and valuable manpower and so on.

I appreciate the opportunity to discuss these matters with you. I will reiterate that I think this Report makes some invaluable contributions to the kinds of policy questions that this task force is looking at. I hope we can incorporate many if not most of your recommendations.

Mr. FUQUA. Thank you, Mr. Brown. Let me again thank our witnesses this morning. Thank you, Dr. Bromley and Mr. Packard, for this very excellent Report. Dr. McTague, we thank you for your contributions this morning also.

The meeting is adjourned.

[Whereupon, at 10:56 a.m., the task force adjourned, to reconvene subject to the call of the Chair.]

APPENDIX

A RENEWED PARTNERSHIP

An examination of federal government-university-industry interactions in U.S. research and higher education in science and engineering.

February 1986

A Report of the
White House Science Council
Panel on the Health of U.S. Colleges and Universities
to the
Office of Science and Technology Policy
Executive Office of the President
Washington, D.C. 20506

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

February 26, 1986

Dear Dr. McTague:

I have the pleasure of transmitting to you the Report of the White House Science Council's Panel on the Health of the U.S. Colleges and Universities, chaired by David Packard with Allan Bromley as Vice Chairman.

The Report, entitled A Renewed Partnership, was discussed in detail with the members of the Science Council and comes to you with their unanimous support.

Both personally and on behalf of the Science Council, I wish to take this occasion to express to the Panel members my appreciation of all the effort that they have devoted to this important study. They have identified the critical issues that must be addressed if we are to retain our national leadership in areas of science and technology that are of central importance to our national future. Their recommendations spell out a national plan of action that merits serious and immediate attention.

Sincerely yours,

Sol Buchsbaum

Solomon Buchsbaum
Chairman
White House Science Council

Dr. John P. McTague
Acting Director
Office of Science and Technology Policy
Executive Office of the President
The White House
Washington, D.C. 20506

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

February 24, 1986

Dr. Solomon Buchsbaum
Chairman
White House Science Council
Washington, D.C. 20506

Dear Dr. Buchsbaum:

The Panel on the Health of the U.S. Colleges and Universities which you established on May 3, 1982 and which I have had the pleasure of chairing has completed its task, and now transmits to you, herewith, its unanimous Report entitled A Renewed Partnership.

We have benefited greatly from input received from representatives of over one hundred universities and colleges and from over forty private sector organizations. This input has bolstered our belief that we still enjoy, in this country, the benefits of the world's strongest scientific and technological enterprise. But at the same time, it raises disturbing problems and questions concerning both the short- and long-term health of this enterprise.

In our Report, we address these problems and questions and make specific recommendations directed to each of the Federal Government, the universities and the private industries. Although we recognize fully that it will be difficult, particularly under our present national fiscal stringencies, to implement all these recommendations, we are confident that their implementation will ensure the continued health and vitality of a higher education system that has served this Nation well.

Sincerely yours,

David Packard
Chairman
Panel on the Health of
U.S. Universities

White House Science Council

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PREAMBLE

America has a unique dependence upon its colleges and universities both for new knowledge and for young minds trained to use this knowledge in innovative ways; the excellence of our colleges and universities has been a cornerstone of our economic well-being, our national security, and the health and quality of life of our citizens. But, as emphasized by the White House Science Council Panel on the Health of U.S. Colleges and Universities, the strength and excellence of this higher education enterprise is at a transition point, and can no longer be taken for granted.

At a time when ever greater demands are being made on our research universities they find themselves, after more than a decade of belt tightening and retrenchment, with aging facilities, obsolete equipment and growing shortages of both faculty and students in many important areas.

The problems discussed in this Panel Report are very real and very important. And the Panel is entirely correct in its conclusion that increased support, important as that will be, is not, in itself, sufficient to ensure the health of our system of higher education. What is most needed is a re-examination and restructuring of the relationships that have evolved among the federal government, the universities, and U.S. industries.

Recognizing the powerful dividends, both short- and long-term, reaped from our universities and colleges, many sectors of society—including state governments, industry, foundations and private individuals—have increased their support of educational institutions in recent years. This commendable commitment to sustained academic excellence reflects a recognition that, just as these benefits accrue to all, so also must the costs be shared by all.

This Administration has made a concerted effort to maintain the Nation's preeminence in an age of rapid technological change and intense international competition. This is evident in the broad measures taken to spur continued economic growth and competitiveness, including reducing the federal deficit, reducing taxes and eliminating unnecessary regulation. It is also reflected in this Administration's provision of increased real funding for basic scientific and engineering research, totaling 30 percent since 1981; especially in our colleges and universities.

As the Panel emphasizes, however, while these actions have been critically important, much remains to be done to offset the neglect of the prior decade. It is essential that we return to the view that federal—and industrial—support of university research and education is an investment in our national future rather than procurement of necessary products and services. Moreover, while the returns from basic research may in some cases be long-term, that represented by the flow of young scientists and engineers trained in the course of this research is immediate and of critical importance.

The Panel presents us with a detailed and careful analysis of the need to develop an effective government-university-industry partnership if we are to maintain our position in an increasingly technological and increasingly competitive world. They have made specific recommendations to this end and to the maintenance of the health and vitality of our universities and colleges.

I believe that their Report deserves the thoughtful consideration of every citizen, and I share the Panel's optimism that, given the partnership and the support recommended, our universities will respond enthusiastically and effectively to the challenges ahead. This report provides an important frame of reference against which to measure our progress and chart our national course.

The road ahead will not be an easy one; but it is the road that, for the national good, we must pursue. Scientists and engineers have a special responsibility to inform themselves about the issues addressed in this Report and then, as individuals, to take action in support of a strong and vital national science and technology base.

The Panel has devoted much thought and effort to their Report, and I would take this opportunity to express to its members my deep appreciation. I take pleasure in commending this Report to all readers—scientist and nonscientist alike—as an important contribution to the charting of our national future.

John P. McTague
Acting Science Advisor to the President

I. EXECUTIVE SUMMARY

1. Overview

The health of U.S. society is uniquely coupled to that of its universities. To a greater degree than any other country this Nation looks to its universities both for new knowledge and for young trained minds prepared to use it effectively. But just at a time when much is expected of our universities, after more than a decade of retrenchment and belt tightening, they find themselves with obsolete equipment, aging facilities, and growing shortages of both faculty members and students in many important fields.

In response to a request from former Science Advisor to the President, George A. Keyworth, for recommendations on how to ensure the universities' long-term ability to provide the talent and research necessary for the Nation's scientific enterprise, the White House Science Council established the Panel on the Health of U.S. Colleges and Universities. Its membership includes representatives from the research community, both academic and nonacademic. This report is the result of their study.

To assess the university system's future, the Panel asked—among others—the following questions: Are our universities attracting the best students into science and engineering? Is the education and training provided adequate to prepare the next generation of scientists and engineers for the challenges of the 21st century? Will our universities be able to respond appropriately as these demands change? Do the environment and support allow researchers to be optimally productive?

The answers to these questions cause us concern. The problems are real and ubiquitous.

We are certainly not alone in recognizing that science and technology are critical to our future. Nations everywhere are investing in these capabilities. We conclude that we must rethink and, in many ways, rebuild the critically important interactions between universities, government, and industry that have served this Nation so well in the past. The federal government-university relationship is too fundamental to the maintenance of our national science and technology base to be taken for granted, and the industry-university partnership is emerging as critical to exploiting that base in order to compete in the world marketplace.

One conclusion is clear: our universities today simply cannot respond to society's expectations for them or discharge their national responsibilities in research and education without substantially increased support. Federal support of university research as a percentage of the gross national product peaked in 1968 and reached a low point in 1978. After increases in 1979 and 1980, it has declined in the 1980's (Figure 1). In 1984, only $8 billion of the nearly $100 billion in total national research and development was performed in universities, a level that simply does not reflect our dependence on the availability of the most able technical talent. An economy whose growth prospects depend upon maintaining a competitive edge in technology must look to an increasing—not decreasing—emphasis on the source of this technical talent. It is time to take an honest look at what the real costs of university-based research are and how they should be borne. We must return to the viewpoint that federal support of such research is a long-term investment in the Nation's future rather than the procurement of a necessary product.

The strength of the nation in trade, defense, and health has been directly related to past investments in science and technology. Our future position in global markets will similarly depend on our willingness to respond to opportunity and to mobilize our strengths today. To this end, we must promote a broad interdisciplinary approach to problem-solving by focusing on university-based centers that will improve cooperative linkages between scientists, engineers, and industry.

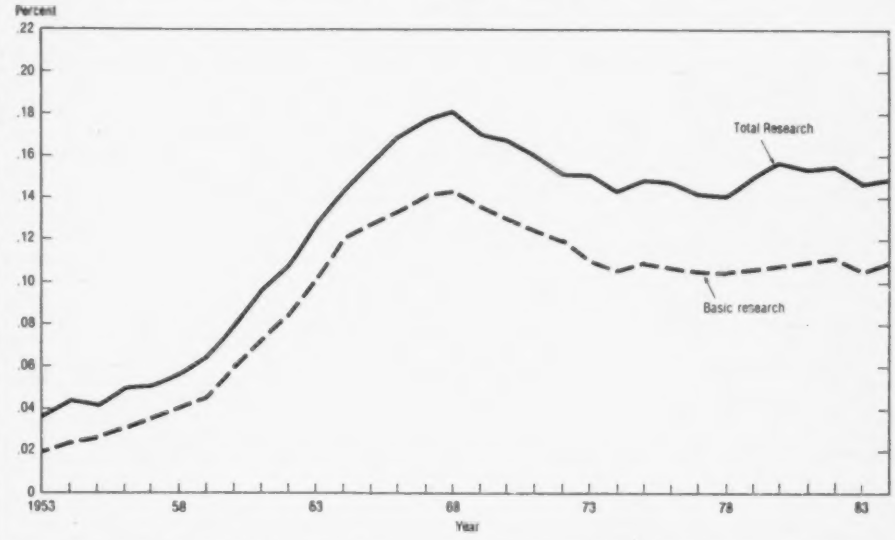
If we are to have an acceptable future in an increasingly technological and competitive world, and if we are to respond adequately to national needs in areas of economic competitiveness, national security, and quality of life for all our citizens, the time has come when a new partnership involving all three, the federal government, universities and the private sector, must be forged. And we must be realistic about the very real limitations on the extent to which industrial support of basic research, important as it is, can replace that from the federal government.

In the summary which follows, we present the Panel's major findings and recommendations. We believe that they demand the attention of the nation, and that if they are implemented, our universities will respond enthusiastically and effectively. Our present leadership in international science and technology is challenged; indeed, many consider it fragile and endangered. We are confident that the actions we recommend will allow us to retain this leadership. We cannot afford less.

2. Findings

- A healthy university system is the basis for our future. In any ranking of priorities for allocating R&D support—both federal and private—universities must rank first.

Figure 1
Federal support of university research as percentage of the gross national product: 1953–1984



- Demands for new talent and new knowledge have never been greater. Universities will not be able to respond to these growing needs without increased federal support. In particular, we encourage continuation of present administration policies to further increase basic research as a fraction of total national R&D funding.

- Of equal importance with the level of funding is the stabilization of federal support to permit more effective use of financial and human resources. The most ambitious research requires long lead times for preparation and incubation. Research groups are exceedingly fragile; once disbanded, they can rarely be reassembled. In the absence of stability and predictability, important opportunities have been lost, scarce resources have been used inefficiently and, most serious, some of the brightest young minds in each recent generation have been lost to science and technology.

- The universities themselves must share the responsibility for the deterioration of their health and capability. In attempting to ride out what were hoped to be temporary budget shortfalls, they mortgaged their research futures too often using limited funds to maintain research personnel rather than investing in needed instrumentation or facilities. Moreover, research faculty members have themselves too often forgone high-risk exploratory research which, were it to succeed, could have impressive payoff.

- State and local governments as well as private philanthropy, play a vital role. Their initial investments develop the structures and programs that make universities competitive for federal investment, and they provide resources by which academic institutions preserve their autonomy and diversity. Moreover, such support is a major element of the shared responsibility that typifies the present university-federal government partnership.

- The diversity of our college and university system is an essential element of its strength.

- In recognition of the leadership demands that our society will place upon them, it is essential that mechanisms be developed for early identification and support of our most able youth.

- Strong university-government-industry partnerships are fundamental to meeting our goals in economic competitiveness, national security, agriculture, health, and in improving the quality of life of our citizens.

3. Recommendations

A. To maintain the strong science base essential to our national future, we recommend that:

1. The federal government make substantially greater investments in our centers of learning in the 1980's and 1990's than in the 1970's. The recommendations set forth in this report, if they are to be implemented fully, require significant increases in financial support. The source of such funding in these times of fiscal stringency is not obvious. Reallocation of R&D appropriations appears to be the most probable source, but we believe that incremental new funding will be required. In any case, we emphasize that this federal investment, at minimum, must keep pace with the overall national investment in R&D; at the current rate of growth it will double in ten years. More rapid growth is essential if our universities are to meet the burgeoning demands being made upon them from almost every sector of our society. The federal government is the only practical source of funding for the major part of this growth.

2. The federal government support a major initiative to establish university-based interdisciplinary, problem-oriented research and technology centers directed to problems of broad national needs and relevant to industrial technology.

3. The federal government bear its full share of the cost of the university research it supports.

B. To build a solid partnership among the federal government, industry, and universities; to enable the university infrastructures to keep pace with research and educational needs; and to assure that the universities are able to pursue research and education effectively, we recommend that:

1. Federal policies recognize that the costs of university research facilities and equipment are a necessary part of federally sponsored, university-based research costs.

2. The portion of federal research grants and contracts that reimburse universities for use or depreciation of facilities and equipment (use allowances) be based on realistic useful lifetimes:
   a. Useful life of buildings and facilities should be reduced from the present level of 50 years to 20 years.
   b. Useful life of equipment and instrumentation should be reduced from the present level of 15 years to 5 to 10 years, depending on the class of equipment.

   These changes, which do no more than inject reality into the costs of doing research, will increase substantially the indirect fraction of total costs. This increase should not be drawn from direct research costs but from reallocation of funds from other sources.

3. To allow U.S. universities to restore their infrastructures in a timely fashion, a facilities fund be established within NSF for each of the next ten years. And that in order to encourage excellence:
   a. All proposals submitted to this facilities fund should be subjected to peer review within the scientific or technological community involved, and
   b. All awards from the fund should be made on a 50/50 matching basis with non-federal funding.

4. Any reorganization of the federal tax code recognize the importance of increased industry-university interaction. A 25 percent nonincremental tax credit should be established for industrial funding of university research and for industry-supported maintenance and servicing of university equipment. A tax deduction equal to the full market value of all industrially contributed equipment should be established.

C. To minimize controversy and friction concerning the reimbursement of indirect costs, we recommend that:

1. Reimbursements for administrative costs within the indirect cost category be fixed at a uniform percentage of modified total direct costs. That percentage should be the mean national percentage over a five-year historical period, and the adjustments should be phased in over a two-year period to allow those universities now charging more than the new fixed rate to plan for reduction. This change will eliminate much of the need for faculty effort reporting.

2. The formal requirement for cost-sharing be eliminated.

3. The paperwork burden associated with grant and contract administration be reduced to a minimum. In the Panel's view, all faculty effort reporting should be eliminated.

4. All federal agencies supporting university research adopt the NSF practice of including the indirect costs in the project budget subject to peer review.

D. In order that the university environment be conducive to high-quality research and education; that it be attractive to the best minds; and to increase the effectiveness with which federal funding is used for research, we recommend that:

1. Federal agencies work toward an average grant or contract duration of at least three, and preferably five, years.

2. Investigators be free to use up to 10 percent of their grant or contract support on a fully discretionary basis and be permitted to carry unexpended funds forward from one fiscal year to the next.

3. Federal agencies make greater use of block grants or contracts to support groups of investigators having shared research interests.

4. For greater flexibility, to facilitate changes in an investigator's field of research, and to support high-risk research, federal agencies, except in the cases of young investigators, place substantially more emphasis upon the research history of the investigator and less on the proposed research project in making awards.

E. To identify and educate our most talented youth more effectively, and to enable experienced scientists and engineers to continue to contribute their skills in a changing technological environment, we recommend that:

1. A substantial program of merit-based, portable scholarships be established by the federal government at the undergraduate level. Parallel programs should be established by industries having significant dependence upon university research and education. The national goal should be for the most able 1 percent of the undergraduate students in mathematics, engineering, and the natural sciences entering colleges or universities each year to be supported under these programs. This program is recommended as an addition to, not a substitution for, existing need-based federal assistance programs.

2. Substantial programs of multiyear merit-based fellowships, both federal and industrial, be established in science, mathematics, and engineering at the graduate level. Reflecting national needs, the field distribution of these fellowships would be expected to change over time.

3. Universities encourage interdisciplinary activities at the graduate level while retaining the essential quality control function now played by the traditional disciplinary departments.

4. Industries and universities develop attractive continuing education programs for engineers and scientists that are matched to contemporary industrial requirements and to modern science and technology.

II. INTRODUCTION

On the wisdom with which we bring science to bear in the war against disease, in the creation of new industries and in the strengthening of our Armed Forces depends in large measure our future as a nation.

Vannevar Bush
Science, The Endless Frontier
p. 194

How we, as a nation, succeed in achieving our goals in matters of health, economic strength and national security will depend critically on how effectively we deploy our science and technology. This, in turn, depends upon the strength of our science and technology base—upon the flow of new knowledge and of trained personnel equipped to utilize that knowledge effectively. As was vividly demonstrated in the radar, atomic energy and medical care advances during World War II, technological developments draw upon a reservoir of basic research in science and engineering, and upon the imagination and creativity of broadly educated scientists and engineers. Indeed, our society's recognition of this dependence underlies the federal support which has given us, in the U.S., one of the world's strongest science and technology enterprises.

Both science and technology are advancing at an unprecedented pace and are strongly affecting the daily lives of our citizens; rarely, if ever before, have such revolutionary changes and advances occurred simultaneously across the entire spectrum of the sciences. Such rapid change poses fundamental challenges and equally fundamental opportunities. If we are to respond effectively to these challenges and opportunities, we need, more than ever, an increasing flow of new knowledge and of trained personnel—a stronger national science and technology base. In this country, we are uniquely dependent upon our universities for both basic research and higher education; perhaps our greatest strength here has been our insistence that the two are inseparable and symbiotic.

But just when much is expected of our universities, many have expressed growing concern about their ability to respond to national needs. The comments we have received from leaders in universities, industry, and government suggest that there are serious problems in the availability of modern research instrumentation and facilities, that overall funding levels are too low to provide appropriate stability to existing research groups as well as allow the entry of promising young investigators, that government regulations impose unnecessary administrative and accounting burdens, and that training in many fields is inadequate for societal needs. Despite increased support in recent years, after more than a decade of level funding, of growing friction in the federal government-university interaction, of inadequate industry-university communication or cooperation, and of student and faculty shortages in many critical fields, the U.S. university system, long the envy of the world, is now under stress. The White House Science Council Panel on the Health of U.S. Colleges and Universities was appointed by Dr. Solomon J. Buchsbaum, Chairman of the Council, and by Dr. George A. Keyworth, Science Advisor to the President, and was charged with an examination of the present health of our university system and with the formulation of policy recommendations designed to ensure that our universities would be able to respond to the growing national demands upon them.

In our study, we have focused upon the natural sciences and engineering, but the health of the entire spectrum of American education—from chemistry to computer science to the classics—is important to our national future. In a society of ever increasing scientific and technical complexity, effective citizen participation requires a degree of scientific and technological literacy that allows appreciation of the central issues involved, if not direct participation in their resolution. On the other hand, the Nation can ill afford generations of scientists and engineers unable to appreciate the economic and social consequences of their work or the underpinning of values and moral judgments that are the primary focus of the humanist.

The reader will find in this Report a brief discussion of the need for university-based research (Chapter IV). In Chapter V, we focus upon the costs of academic science and engineering, with particular reference to the question of indirect costs which have been a root cause of much of the growing friction and alienation between universities and the federal government. Finally, in Chapter VI, we consider the environment for academic science and education, and the opportunities and responsibilities that government, industry, and the universities each face in making it more effective.

After each of these chapters, we collect our primary findings and recommendations for the reader's convenience; the major ones are again presented in the second part of our Executive Summary.

III. THE NEED FOR UNIVERSITY-BASED RESEARCH

The value of fundamental research does not lie only in the ideas it produces. There is more to it. It affects the whole intellectual life of a nation by determining its way of thinking and the standards by which actions and intellectual production are judged. . . . An atmosphere of creativity is established which permeates every cultural frontier. Applied science and technology are forced to adjust themselves to the highest intellectual standards which are developed in the basic sciences. . . . Fundamental research sets the standards of modern scientific thought; it creates the intellectual climate in which our modern civilization flourishes. It pumps the lifeblood of idea and inventiveness not only into the technological laboratories and factories, but into every cultural activity of our time. The case for generous support for pure and fundamental science is as simple as that.

V. F. Weisskopf
Bulletin of the Atomic Scientists
April 1965

1. Introduction

From the beginning of this nation, its genius has been the speedy and effective conversion of new knowledge into useful goods and services. In our earliest days we tended to draw upon the reservoirs of basic discovery filled elsewhere—particularly in Europe; our aim was its conversion to practical use. Our focus was on the mastery of nature rather than its understanding—on invention rather than natural philosophy—and the two were considered quite distinct and separable until the pressures of World War II demonstrated their intricate and essential connections. These connections can be subtle and indirect. Basic research—the understanding of nature—is not necessarily linked to any specific technological orientation; the engineer or technologist cannot tell in advance what basic research result may be of greatest relevance to his work. Some basic research—that leading to X-rays, for example—may find important medical and technological applications within months of the original discovery. This, however, is not the common experience. Much basic research is not translated into application for decades after discovery.

Reflecting the enormous spread in lag times between discovery and application, it is very difficult, if not impossible, to document a very general visceral feeling shared by the Panel members and by a very large fraction of the scientific and technical community that the process of utilization—the transfer of new knowledge into goods and services—is accelerating. This may not reflect a change in the fundamental mechanisms whereby these transfers are accomplished, but rather a rapidly growing recognition of the potential benefits to be derived from the possible applications of scientific and engineering discoveries and the increase in the number of individuals qualified to, and interested in, making such applications.

This is more obvious when we consider the international marketplace in which we now function. For several decades following World War II, the U.S. set the style and pace of scientific and technological activities worldwide. We chose those areas which were to receive emphasis. This situation is now dramatically different, not because of any slackening on our part, but simply because the rest of the world is catching up, and, in a few areas, surpassing us in the ability to discover and exploit new knowledge.

It has become increasingly important that the basic research reservoirs from which *all* draw in a technological world be kept filled for use by engineers and scientists devoted to the production of goods and services for society. The interaction between basic science and technology is one of symbiosis. Basic science has continued to press the frontiers of knowledge and at the same time has been dependent upon the skill and ingenuity of engineers for its progress. By participating in the achievement of national goals, basic research is made no less pure, no less exciting; it is, however, made more challenging, more rewarding, and more important when better appreciated and better utilized.

Basic science frequently finds entirely new challenges and new directions from the needs of the world. There are many examples from which we select three: DNA in biology was discovered as the outcome of a study of the scourge of pneumonia; complexity theory in abstract mathematics was discovered as an outcome of attempts to understand the functioning of simple electronic computers; and universal cosmic black body radiation in astrophysics was discovered as the outcome of

an attempt to understand the source of noise in satellite communications systems.

It is the combination of new knowledge from basic research and of minds that can appreciate the practical applications that provide the most fertile source of innovation.

2. Graduate Education and Research

As graduate education flowered in this country's universities in the latter part of the nineteenth and early part of the twentieth centuries, its industrial support flowed from a recognition of the universities' importance in the education of scientists and engineers and the discovery of new knowledge. Both were understood as essential to progress. It was only with World War II, however—and the scientific and engineering triumphs of radar, atomic energy, medical care and the like—that U.S. society more fully recognized the importance of basic research and, more particularly, its potential importance in matters of health, national security and economic strength. It is this recognition that lay behind the subsequent great increase in federal support of U.S. university research activity.

From the outset of graduate education in the U.S., particularly in science and engineering, an intimate connection between education and research has been considered fundamental to the production of creative scientists and engineers. Our focus on this linkage has served the Nation well. Very much a part of this focus is the fact that most of U.S. basic research is conducted in our universities, making these universities critical to our national science and technology enterprise. A strong confirmation of the effectiveness of our university system indeed comes from the number of foreign students studying science and engineering in this country.

Since most basic research can rarely be perceived in terms of specific products and services, and given the long-range nature of such research, private industry does not often support a high level of basic research. If one thing has become clear in recent decades, it is that the fruits of basic research provide benefits for all of society, frequently in ways not visible initially to any of the participants. It is for these reasons that the federal government has become, and remains, the primary supporter of basic research in this country.

3. Federal Support of University Research

The major surge in federal support for scientific research in universities came as a consequence of the experiences of the Second World War. In particular, the prewar-postwar transition is epitomized by the report *Science, the Endless Frontier*, and the agency to which it led, the National Science Foundation (NSF). The report, prepared by Vannevar Bush in 1945 at the request of President Truman, for the first time articulated a federal policy which accepted responsibility for the support of research, and of basic research in particular. Establishment of NSF in 1950 was the logical outcome of this policy. In contrast to the targeted support of mission agencies, the National Science Foundation Act of 1950 directed that the objective of the Foundation be ". . . to strengthen research and education in the sciences, including independent research by individuals . . ."

This language clearly indicated that the purpose of federal involvement should be in the nature of an *investment* in research. Spurred also by Sputnik in 1957, the result was a strong influx of funds into R&D generally and into the universities specifically. As shown in Table 1 and Figure 2, from 1953 to 1961 federal funding of R&D increased 14 percent annually, in constant dollars. The rate of increase in federal funding at universities reached its peak between 1958 and 1964, increasing an average 21.8 percent annually, in constant dollars (Figure 3).

In 1968-1969 however, growth came abruptly to a halt, and for the next decade showed essentially no increase in real terms. Although the universities increased their own expenditures in R&D almost 50 percent during this period (Figure 4), this could not even come close to providing a reasonable rate of growth for the system.

In parallel with this halt in funding, was a halt in the growth of manpower engaged in university R&D. Between 1954 and 1968, full-time scientists and engineers engaged in R&D at universities increased more than two-fold and the graduate student population more than tripled. However, between 1968 and 1974 growth in these groups was essentially zero (Table 2).

The damage resulting from this long period of stasis and decay cannot be overestimated. Since universities conduct more than 60 percent of the basic research performed in this country, the absence of growth was reflected in a significant deterioration in this nation's ability to promote technological advances. In an era when science and technology are the key to economic success, such a decline implies a drop in the standard of living of all members of the society, and indeed poses a threat to the future of this country in international competitiveness.

No less serious is the loss of trained manpower, and for the same reasons. Graduate training is essential to providing industry, academia, and the federal establishments with individuals capable of initiating, exploiting, and maintaining technological advances. And even beyond this, the limitations on the universities' ability to provide educational opportunities adequate in either scope or quality limited the ability of a significant proportion of our youth to reach their full potential. This represents a tragic loss not only for the individuals involved, but also for society as a whole.

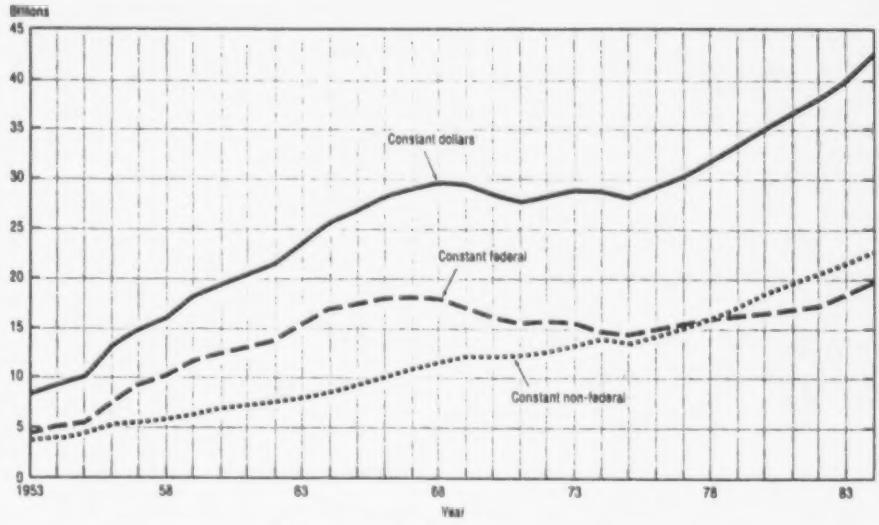
During this period of stagnation, several specific phenomena occurred which have affected the capabilities of the universities to this day. Direct federal support of R&D plant in the univer-

Table 1: Average Annual Change in National R&D Funding 1953-1984
(In Percent)

	Current Dollars			Constant Dollars		
Year	Total	Federal	Non-Fuderal	Total	Federal	Non-Federal
1953-61	13.7%	18.4%	10.0%	11.4%	14.0%	7.7%
1961-67	8.3	7.6	9.5	6.0	5.3	7.2
1967-75	5.4	2.9	8.7	−.7	−3.0	2.4
1975-79	10.0	9.1	11.0	3.5	2.6	4.5
1979-84	11.9	10.8	12.7	4.9	3.9	5.9

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1984*

Figure 2
National R&D funding trends: 1953–1984 (constant 1972 dollars in billions)



SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1984.*

sities dropped from $211.7 million (in 1972 constant dollars) in 1966, to $19.5 million in 1981. In 1966, the percentage of the budget of NIH research grants devoted to instrumentation was 11.7 percent (Figure 5). For NSF, the comparable value in 1966 was 11.2 percent. By 1982, this percentage was about 4.5 percent for NIH and 9 percent for NSF. Since NIH and NSF have consistantly contributed two-thirds of the federal support for university instrumentation, these decreases clearly have been significant. The inadequacy and decay of the physical plant, and the obsolescence of the equipment pool have been extensively documented in recent years (Figure 6). There can be little doubt that they severely limit the research productivity and creativity of the universities.

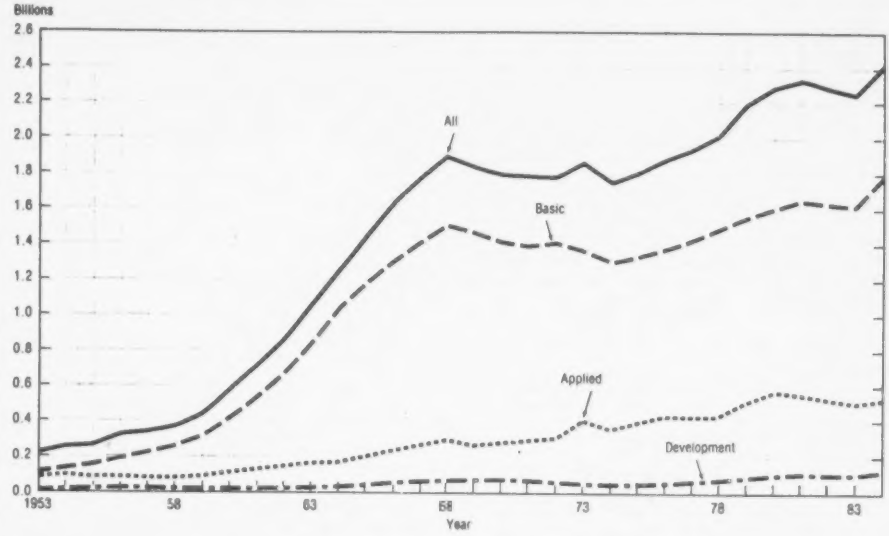
4. Increasing Costs of Research

In addition to the general inflation which affects the broader reaches of society, there is another form of cost increase intrinsic to much research and technological progress. Major advances can still result from individual genius and from simple pencil and paper studies, but it is fundamental to the nature of empirical research in any field that each new experiment tends to require more sophisticated equipment, more complex techniques, more adept and creative researchers, and purer materials, for example. This simply reflects the increasing difficulty with which deeper understanding is wrested from nature. It appears in virtually every field of science. In medical research, simple X-ray machines that once provided invaluable information to researchers and physicians now are little used, but have been replaced by more capable (and more complex and more expensive) computer-assisted tomography (CAT) scanners and nuclear magnetic resonance (NMR) machines. In particle physics, simple bubble chambers are no longer capable of providing new insight to scientists; huge and much more sophisticated detectors with real-time links to very large computers to process huge volumes of new data are required. Indeed, in virtually every area of research, investigators now use and require extensive computer time, where not many years ago it simply did not exist. Evidence suggests that nonpersonnel costs of high technology R&D have risen some 50 percent faster than has the consumer price index.

5. Investment or Procurement?

Perhaps most important, the decline in the growth of federal support coincided with a change in the way the federal government viewed its involvement with universities and university-based research. From an emphasis on long-term investment

Figure 3
Federal expenditures on university research: 1953-1984
(constant 1972 dollars in billions)



SOURCE: *National Patterns of R&D Resources: Funds and Manpower in the United States, 1953-1975; National Patterns of Science and Technology Resources, 1984*

there has been a progressive shift to a procurement approach and philosophy. This is evident from the data on investment in capital equipment and facilities. In addition, the imposition of onerous accounting procedures has produced an unnecessary cost burden, and has severely restricted the ability of individual investigators and institutions to respond promptly and effectively to new opportunities. The operation of the project grant system has shifted from primary reliance on the capabilities and vision of talented investigators, to insistence on the detailed presentation and achievement of specific goals.

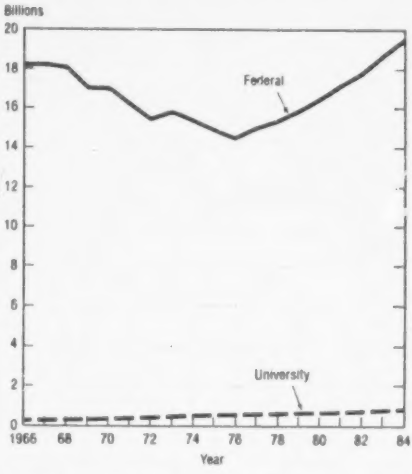
This lack of trust and confidence in our investigators and research institutions appears to the Panel to be totally unjustified. The university system has served this country well in its primary missions—the conduct of basic research and the training of young minds. The adversarial relationship which has developed in many areas of university-government relations, as in assessment of indirect costs (see next chapter), is damaging both parties in their common pursuit of the goal of a better national future.

It must also be said, however, that the blame for deterioration in the health of the American university research system must be shared. Universities, by and large, had little choice but to take a short-range perspective in managing their resources. In general, each year's decline in federal support was rationalized as a temporary aberration from the natural order. Consequently, universities tended to defer decisions on long-term needs in an attempt to protect, in the short term, their most valuable assets, their people. Although this policy was understandable, it represents a failure in management and planning, and universities are now living with its consequences.

6. Rebuilding University Research

The decline between 1968 and 1975 in growth of federal funding of research has been reversed in recent years. Beginning in 1975, total federally supported R&D has increased steadily. Between 1981 and 1984, Federal support for R&D increased by 14.3 percent and for basic research by 7.1 percent (per Figure 7). A concentrated effort, however, will be needed during the next few years to sustain these recent support trends. The Panel is unanimous in its view that the Nation's demand for talent and for new knowledge will not be met without a substantially greater federal investment in university research—with much of the increase devoted to upgrading and strengthening of the university research infrastructure. We are convinced, moreover, that this increased investment will require both a new set of priorities for expenditure of federal R&D funds and increased support of university activities.

Figure 4
National expenditures for R&D by source: 1966-1984 (constant 1972 dollars in billions)



SOURCE: *National Patterns of Science and Technology Resources, 1984.*

Currently, only about 20 percent of total federal civilian R&D funding is devoted to the support of basic research in the universities and only about 30 percent to academic research of all kinds. **Of the almost $100 billion expended nationally in 1984 for research and development only about $8 billion found their way to universities. Such a balance is simply not appropriate to today's demands for the talent and new knowledge that only universities can provide.**

Based on all the information available to it, the Panel is convinced that full implementation of the recommendations in this report will require significant increases in financial support for basic research in the universities. The source of such funding in these times of fiscal stringency is not obvious. Reallocation of R&D appropriations appears to be the most probable source, but we believe that incremental new funding will also be required. In any case, we emphasize that future investment in university basic research must at least keep pace with the overall investment in national R&D; at the rate this is currently growing, the investment in real terms will double in ten years. This is simply not adequate to permit the universities to respond effectively to the demands being made upon them from almost every sector of our society. **We must make a greater commitment to our centers of learning in the 1980's than was provided to them in the 1970's, and the federal government must take the lead for the major fraction of that support.**

7. Importance of Stability

It is essential, too, to recognize that stable and predictable growth, not intermittent infusion of funds, is essential. Violent

TABLE 2
FULL-TIME EQUIVALENT (FTE) SCIENTISTS AND ENGINEERS EMPLOYED IN RESEARCH AND DEVELOPMENT, BY SECTOR: SELECTED YEARS[1]

Sector	1954	1958	1961	1965	1968	1969	1970	1971	1972	1973	1974	1975[2]
Total	237.1	354.6	425.7	494.1	550.4	558.2	549.6	529.8	521.9	521.1	527.2	530.5
Federal Government[3]	37.7	46.0	51.1	61.8	68.1	69.9	69.8	66.5	65.2	62.3	65.0	64.5
Industry[4,5]	164.1	256.1	312.0	348.4	381.9	385.6	375.5	358.4	353.3	357.4	357.9	358.0
Universities & Colleges total	25.0	36.5	42.4	53.4	66.0	68.3	68.5	68.4	66.5	64.8	66.7	71.0
Scientists and engineers	20.3	29.2	33.6	40.4	49.0	50.4	50.3	49.8	48.9	43.2	49.2	52.6
Graduate students[6]	4.7	7.3	8.8	13.0	17.0	17.9	18.2	18.6	17.6	18.6	17.5	18.4
University associated FFRDC's, total	5.0	8.1	9.1	11.1	11.2	11.6	11.5	11.5	11.7	12.0	12.1	12.8
Scientists and engineers	4.9	7.9	8.8	10.7	10.7	11.1	11.0	11.0	11.3	11.7	11.8	12.4
Graduate students[6]	.1	.2	.3	.4	.4	.5	.5	.5	.4	.3	.3	.4
Other nonprofit institutions[4,7]	5.3	7.9	11.1	19.4	23.2	22.8	24.3	25.0	25.2	24.6	25.5	24.2

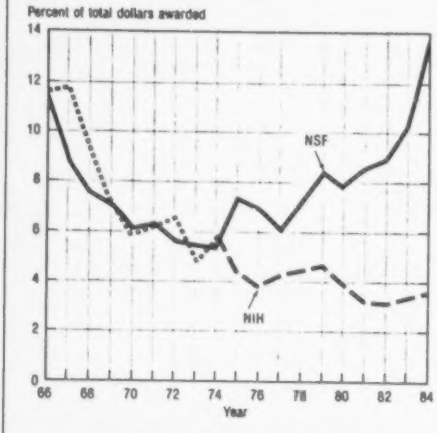
[1]Number of full-time employees plus the FTE of part-time employees. Excludes scientists and engineers employed in State and local government agencies.
[2]Estimate.
[3]Includes both civilian and military service personnel and managers of R&D. Military R&D scientists and engineers in the Department of Defense were estimated at 7,000 in 1954; 8,400 in 1958; 9,200 in 1961; 12,000 in 1965; 13,000 in 1968; 14,000 in 1969 and 1970; 12,000 in 1971; 10,700 in 1972; 8,100 in 1973, 7,600 in 1974, and 7,700 in 1975.
[4]Includes professional R&D personnel employed at FFRDC's administered by organizations in the sector.
[5]Excludes social scientists.
[6]Numbers of FTE graduate students receiving stipends and engaged in R&D.
[7]Includes estimate for R&D scientists and engineers employed in State affiliated institutions such as hospitals, museums, etc.

NOTE: The figures for the industry sector represent yearly averages and may differ from other data in the text which is based upon surveys reporting the employment in a single month of the year. Data in the text exclude historians, political scientists, and other social scientists.

SOURCE: National Patterns of R&D Resources.

Figure 5

Proportion of NSF and NIH grant funds allocated for permanent laboratory equipment



• • NIH estimate for 1966 through 1974 includes only data from the National Cancer Institute, the National Institute of General Medical Sciences, and the National Heart and Lung Institute.

SOURCE: The NSF data is obtained from *Science Indicators, 1974*, and Jim Hoehn, personal communication. The NIH data through 1974 is obtained from *Science Indicators, 1974*. After 1974, the data is from the internal NIH files, and reflects the total contribution of grant funds to equipment.

fluctuations from year to year (and recently even within fiscal years) irrevocably disrupt research groups and programs and effectively halt planning.

Beyond this stable growth in the support of university-based research, additional support is urgently needed to reverse the decay in physical plant and obsolescence in research equipment that has occurred in the past decade. We cannot afford to wait for the slow catch up that would be possible under an acceptable steady-state support scenario.

We believe that the more realistic use allowances for facilities and equipment that we recommend elsewhere in this Report and the recently approved inclusion of the costs of capital in the allowable federal indirect cost recovery pool will provide a significant part of the flow of resources that will enable the universities to maintain and modernize their facilities and equipment, but we emphasize that such resources alone will not suffice.

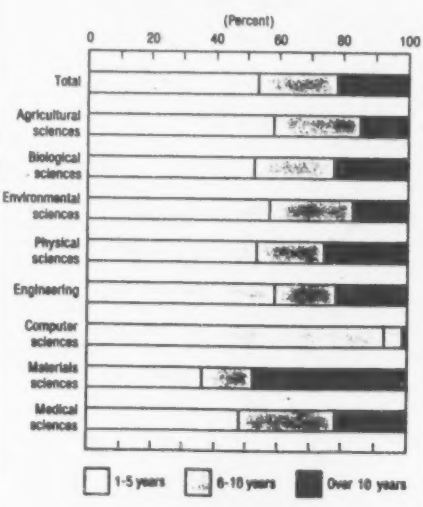
8. Restoring University Infrastructure

Some corrective action is already underway. Federal agencies, encouraged by Congressional concerns, have already initiated new programs to support purchase and renovation of research equipment. We applaud the initiative taken by Representative Fuqua, Chairman of the House Science and Technology Committee, in introducing H.R. 2823, "A Bill to assist in revitalizing the Nation's academic research programs by requiring specified federal agencies to reserve a portion of their research and development funds for the replacement or modernization of laboratories and other research facilities at universities and colleges." We also appreciate the spirit in which this Bill was introduced as a basis for national discussion of this important issue.

The Panel would differ with H.R. 2823 in two important aspects, however. We would recommend that the program be focused in the NSF rather than be distributed across the six major federal R&D agencies in order to minimize bureaucracy and foster uniform standards and procedures. We would also, and more important, recommend that the funding proposed in H.R. 2823 be provided incrementally to the present R&D support levels rather than, as proposed in H.R. 2823, a 10 percent part of the present support levels. As we argue throughout this Report, these present support levels are already inadequate to the national demands on the universities. Given this fact, important as the demands for infrastructure are, were they to be met by an effective 10 percent cut in the level of support for actual

Figure 6

Age distribution of academic research instrument systems: 1982-83

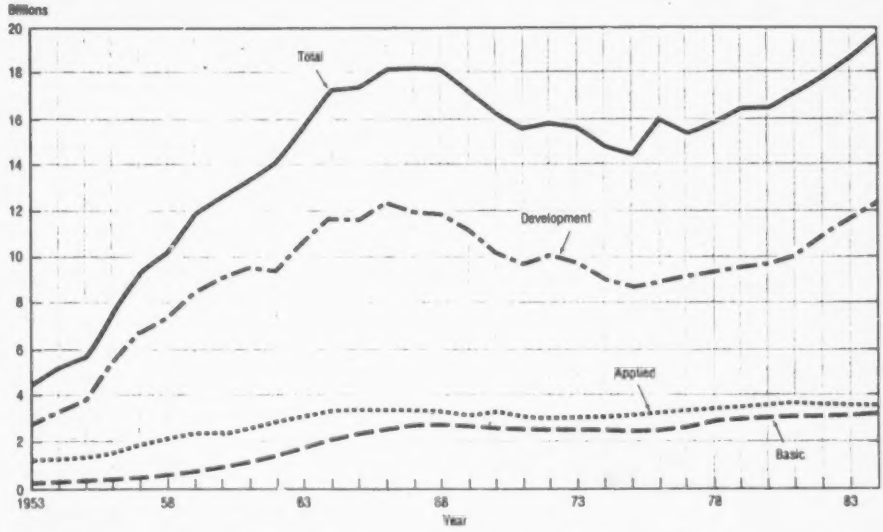


NOTE: All statistics are national estimates encompassing the 157 largest R&D universities and the 92 largest R&D medical schools in the nation. Agricultural, biological and environmental sciences estimates are as of December 1983. For all other fields, estimates are as of December 1982. Sample is 6995 instrument systems.

SOURCE: National Science Foundation, *Academic Research Equipment in the Physical and Computer Sciences and Engineering* (1985), and unpublished tabulations.

Science Indicators—1985

Figure 7
Federal support for research and development: 1953–1984 (constant 1972 dollars in billions)



SOURCE: *National Patterns of R&D Resources, Funds and Manpower in the United States, 1953–1975; National Patterns of Science and Technology Resources, 1984*

R&D, the consequences within the university research community would be devastating.

We therefore recommend that in order to allow U.S. universities to bring their infrastructures—facilities and equipment—to an acceptable level in timely fashion—to catch up—a temporary facilities fund be established, within the NSF, for each of the next ten years. In order to encourage excellence, we recommend that awards from this fund should be made only on a 50/50 matching basis with non-federal funding and that all proposals submitted to the fund be subjected to peer review within the scientific or technological community involved.

The magnitude of the university infrastructure shortfall has been examined extensively in recent years with estimates covering a very wide range. Quite independently of the Fuqua initiative, the Panel arrived at the same estimate of the necessary minimum program scope—$10 billion over the next 10 years with $5 billion from federal and $5 billion from non-federal sources.

9. Realistic Use Allowance

Although a facilities fund is required for "catch-up" purposes, once again efforts must be made to ensure that the program provides continuous support to prevent the boom-bust syndrome of the past. In order to encourage continuity and stability in this area as well, the panel recommends that the average useful life of university buildings and facilities be recognized as being closer to 20 years, compared to the current assumption of 50 years. Similarly, the useful life of equipment and instrumentation should be considered as 5-10 years, depending on the class of equipment, compared to the present level of 15 years. This should be translated into the appropriate levels of use allowance in the negotiated indirect costs, thereby allowing an appropriate recovery of funds to allow continuing maintenance and construction, as necessary in the universities.

We further recommend that reimbursements for interest on borrowed capital (which is now incorporated into total acquisition cost of a laboratory or instrument) should be made a separate category in the OMB A-21 directive on indirect costs. This separation will avoid any possibility of misunderstanding as this relatively new component of allowable indirect costs increases rapidly with the initiation of more university renovation and building.

10. Relationship with Industry

It is clear that the government-university interactions have had considerable impact on both participants. Industry-

university interactions, as noted earlier, have been much more limited and, except in unique cases, of much less importance.

Industry has long had direct links with universities, usually on a one-to-one basis, with some fields having closer relationships than others. But these relationships have depended, in large part, on very unique individuals, and their practices were not widely copied in either U.S. industry or the universities. Much more widespread, of course, are individual faculty consulting relationships.

During the late seventies, however, it began to be recognized that the pace of international technological change required a greater awareness by U.S. industry of university research developments. Moreover, widespread predictions of growing shortages of qualified electronics engineers and computer scientists, and indeed shortages in almost all engineering, mathematics and physical science disciplines, led many companies to reconsider their university ties and their roles in university affairs. While their actual direct research funding levels in support of university activities are still less than 10 percent of the federal government's, industry has begun to develop a wide range of mechanisms for interacting with universities. Particularly important is the assistance that industry can give in providing information to university researchers on areas of basic research that may form the background to the solution of recognized current or future practical problems. In this context, cooperative research through individual contracts, industrial affiliates programs and university cooperative research centers have all received growing attention and support. The federal government has attempted to support these trends by joint funding of cooperative research programs and by supporting innovative new university problem-solving centers.

Perhaps most important of all in the growing rapprochement of U.S. industries and universities is the dissipation of stereotypes developed during the postwar years of readily available federal funds for universities. Both industry and the universities were diminished and weakened by the breakdown, during this period, of their former interactions and channels of communication. Industry can, and must, bring to universities a renewed appreciation of the challenges and opportunities that exist in industry and in the international marketplace; universities, in turn can, and must, bring to their industrial partners a renewed appreciation of the contributions that well-trained, bright young minds—as well as the fruits of university-based research—can make to retaining for U.S. industry a leadership role in a rapidly evolving, increasingly technological, and increasingly competitive world. Industries are thus finding themselves dependent upon the university system for both talent and new knowledge, the products of university education and research activity. Current industrial support of the universities, however, does not measure up to this dependence.

The Panel believes that the federal government can—and should—act to promote greater industrial participation in university activities and that such participation is very much in the national interest. We therefore recommend that a 25% R&D tax credit should be extended to cover fully industrial research expenditures in academic institutions. We further recommend that this deduction should not be incremental but rather a full deduction and that a tax deduction for the full market value of equipment contributed to academic institutions should be established.

11. Multidisciplinary Science and Technology Centers

Of greatest importance, however, is the need to use the existing strengths of both the universities and industry jointly to address problems of long-range national scope. In order to ensure that we can recognize and seize technological opportunity, we must create a research environment that can facilitate change across disciplinary boundaries. A first step has been taken in that direction through the formation, at NSF, of multidisciplinary problem-oriented engineering centers. It is necessary now to expand this concept from the narrow engineering focus to the broader view of science and technology centers.

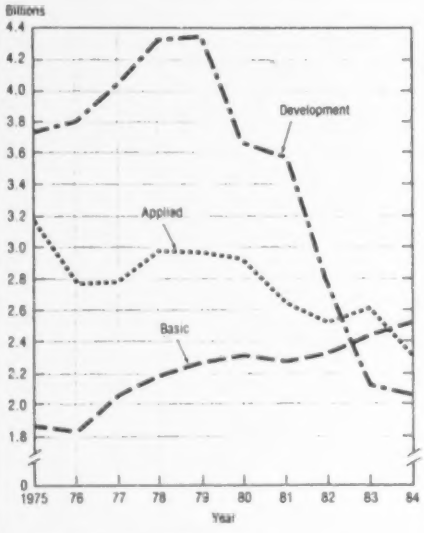
Much of the most exciting research to be undertaken in the future will not fall within the traditional natural science disciplines. As the questions relating to science and technology become more complex, and demand teams of researchers with a broad range of expertise, it will be to the Nation's advantage to provide multidisciplinary centers for their solution. Indeed, it is increasingly the case that the most exciting and fruitful research opportunities are to be found in the interface areas between the traditional disciplines. As presently constituted, the universities cannot comfortably accommodate interdisciplinary research. It will be important for the federal government to provide funding to enhance these interdisciplinary activities within the universities.

The rationale for such an approach has already been stated, but is worth repeating. Emerging technologies are the foundation of industrial competitiveness, and depend heavily on future developments in basic research. Consequently, we find the demand for trained manpower and effective knowledge-transfer growing steadily. This can be most effectively stimulated by the federal government through support for "strategic research," i.e., basic research carried out with the expectation that it will provide a broad base of knowledge necessary as the background for the solution of recognized practical problems.

An emphasis on basic research is consistent with recent government policy. In 1981, development was the largest part of the non-defense federal R&D budget, and basic research was the smallest. By 1984, that ratio had completely reversed (Figure 8). We support such a policy, and would recommend a major initiative in the federal support of basic research in universities through the establishment of research and technology centers directed to problems of broad national needs and relevant to industrial technology.

In making this recommendation, it bears emphasis that a number of universities have already accumulated substantial experience over many years in bringing together federal, industrial, and university interests in collaborative research projects and centers; it is important that the lessons to be derived from this experience be incorporated in all new initiatives in this area. Much basic research does not lend itself to the large-center approach; preservation of the natural diversity of the basic research enterprise is essential. It will also be important to recognize and make due allowances for those areas of basic

Figure 8
Federal non-defense R&D expenditures (constant 1972 dollars in billions)



SOURCE: *National Patterns of S&T Resources*, 1984

research that may either in fact or in perception appear to be displaced or frozen out by the larger, more newsworthy, or more topical center activities.

Despite the substantial increases in industry participation in university-based research in recent years, it should be noted that the supply of industry resources for—and of industry interest in—such activities cannot be expanded indefinitely. It is essential that this be borne firmly in mind in responding to university initiatives for the creation of new science and technology centers.

12. Recommendations

1. The federal government should make substantially greater investments in our centers of learning in the 1980's and 1990's than in the 1970's. The recommendations set forth in this report, if they are to be implemented fully, require significant increases in financial support. The source of such funding in these times of fiscal stringency is not obvious. Reallocation of R&D appropriations appears to be the most probable source, but we believe that incremental new funding will be required. In any case, we emphasize that this federal investment, at minimum, must keep pace with the overall national investment in R&D; at the current rate of growth it will double in ten years. More rapid growth is essential if our universities are to meet the burgeoning demands being made upon them from almost every sector of our society. The federal government is the only practical source of funding for the major part of this growth.
2. The investment approach to university research, recognizing and contributing to the long-term health of the university research system, must be maintained through stable and continued support.
3. The federal government should support a major initiative to establish university-based interdisciplinary, problem-oriented research and technology centers directed to problems of broad national needs and relevant to industrial technology.
4. Federal policies should recognize that the costs of university research facilities and equipment are a necessary part of federally sponsored, university-based research costs.
5. The portion of federal research grants and contracts that reimburse universities for use or depreciation of facilities and equipment (use allowances) should be based on realistic useful life-times:
   a. Useful life of university buildings and facilities should be reduced from the present level of 50 years to 20 years.
   b. Useful life of equipment and instrumentation should be reduced from the present level of 15 years to 5 to 10 years, depending on the class of equipment.

   These changes, which do no more than inject reality into the costs of doing research, will increase substantially the indirect fraction of total costs. This increase should not be drawn from direct research costs but from reallocation of funds from other sources.
6. To allow U.S. universities to restore their infrastructures in timely fashion, a facilities fund should be established within NSF for each of the next ten years. And that in order to encourage excellence:
   a. All proposals submitted to this facilities fund should be subjected to peer review within the scientific or technological community involved, and
   b. All awards from the fund should be made on a 50/50 matching basis with non-federal funding.
7. Reimbursements for interest on borrowed capital (which is now incorporated into total acquisition cost of a laboratory or instrument) should be made a separate category in the OMB A-21 directive on indirect costs.
8. Any reorganization of the federal tax code, should recognize the importance of increased industry-university interaction. A 25 percent nonincremental tax credit should be established for industrial funding of university research and for industry-supported maintenance and servicing of university equipment. A tax deduction equal to the full market value of all industrially contributed equipment should be established.

IV. THE COSTS OF ACADEMIC SCIENCE AND ENGINEERING

No nation can maintain a position of leadership in the world of today unless it develops to the full its scientific and technological resources. No government adequately meets its responsibilities unless it generously and intelligently supports and encourages the work of science in university, industry, and in its own laboratories.

President Harry S. Truman
September 6, 1945

1. Introduction

The combined efforts of government, industry and the universities have, over the years, given the United States one of the finest university systems in the world—both in scope, and in many quality measures as well. Through their tremendous diversity and accessibility, our universities have made the U.S. a world leader in science and technology. The evolution of the system has produced peaks of excellence in both public and private institutions, and across virtually all academic disciplines. Our universities continue to educate top-quality scientists and engineers, and to develop new scientific and technological insight and understanding.

In recent years, however, disputes have arisen over the costs of federally sponsored research at universities, over what those costs actually are and who should bear them. As disputes have intensified, the mechanisms for maintaining a healthy university system have broken down. For example, mistrust between universities and government agencies has led to micromanagement of the research enterprise by the agencies and the imposition of cost accounting paperwork burdens that reduce efficiency and creativity in both research and education. **The Panel believes that the time is ripe to reexamine the controversy over the costs of research and to create a system that maintains the health and excellence of our universities.**

2. The Costs of University Research

Because of the interweaving of education and research in U.S. higher education, it has never been easy to quantify the actual costs of university research. Some costs, such as those for specialized equipment, can be clearly related to research. Others, like utility costs, are more difficult since part is related to research and part to education. Accountants have divided the costs of research into two categories: direct and indirect costs. Direct costs are those attributable to specific projects—costs such as time and effort of the principal investigator, project-specific research equipment, travel expenses and so on. Indirect costs are those not easily allocatable to specific projects; examples include the lifetime costs of laboratory space and research equipment, administration, utilities, etc. The separation into these two categories, direct and indirect, is arbitrary and differs from institution to institution.

When the federal government awards a research grant or contract to a university, it agrees to reimburse that university for a set of costs attributed to that particular project. The reimbursement includes both a direct and an indirect cost. (A detailed discussion of indirect costs can be found in Appendix F.) The amount of the grant is based upon the direct costs and an additional percentage of the direct costs to cover indirect costs. The percentage, known as the Indirect Cost Reimbursement rate, or ICR rate, is agreed to by negotiations between the federal government and the university. Currently, the Departments of Health and Human Services and Defense represent the federal government in such negotiations for all of the agencies that support work in a particular university. Generally, the university will compile documentation of all costs it classifies as indirect in a given time period and attempt to determine how much of each category of indirect costs is attributable to research. The total indirect costs attributable to federally funded research is then divided by the institution's total modified direct research cost reimbursement (the "organized research base") to determine that institution's ICR rate. The indirect costs attributable to unsupported research and to other institutional activities are borne by the institution.

The Office of Management and Budget Circular A-21 attempts to define the costs of research eligible for federal reimbursement (see Appendix F). It also establishes criteria for documentation and allocation of costs, and for negotiation between federal agencies and the universities. Circular A-21 provides a framework for discussion. It has not, however, significantly reduced the controversy over the costs of research.

3. The Controversy Over Research Costs

There are three basic groups at odds in the controversy over the costs of research: faculty researchers, university administrators and government administrators. For each group, the combination of rising costs and slower growth in federal research budgets creates a different problem. To faculty researchers (and federal agencies) the problem is that indirect cost reimbursements are crowding out those for direct costs. Less and less of every research dollar is going to investigators and more and more to university administration. To university administrators, the problem is simply that reimbursements are not keeping pace with total actual university research costs. Government agencies are concerned that university research is becoming increasingly expensive at a time of increasing demands for the results of that research—talent and knowledge—and of limited federal research funding. They recognize that they will be under increasing pressure to increase the pace and scope of university research, and yet they are already in trouble funding it at its present level. They are also concerned that the research community is not, in their view, providing an adequate accounting to the taxpayers for the support received.

The controversy arises as the three groups try to reconcile their competing perspectives. Many faculty researchers, seeing their direct cost reimbursements crowded out by indirect cost reimbursements at a time when university bureaucracies often appear to them to be burgeoning, suspect that at least some indirect cost reimbursement claims are not entirely reasonable or necessary. These suspicions are reinforced by the perception that universities have few incentives to contain indirect cost reimbursements. Many government administrators, searching for ways to cut back on indirect cost reimbursements, are struck by the wide variation in ICR rates among institutions (see Table 3) and thus share with the researchers the suspicion that perhaps not all claims are reasonable and necessary. In addition, some government officials wonder whether it is even necessary or proper, particularly during a time of limited research funding, for the government to reimburse universities for all the costs they claim, even when those costs are legitimate.

It bears emphasis in any consideration of the variation of ICR rates that private and public universities really cannot be judged on a common scale. In general in the public institutions, state legislatures provide support for many aspects of infrastructure costs that in the case of the private institution become part of the federal indirect cost pool. In Table 3, for example, public institutions typically have ICR rates below 50 percent and private institutions in excess of 50 percent.

University administrators respond to faculty members and government officials with four points. First, they argue that the causes of the increases in indirect costs are real, citing as typical examples the needs for facilities and equipment, and growth in energy and library costs. The growing university bureaucracies, they contend, are a response to the proliferation of government red tape. Second, they argue that it is meaningless to compare indirect cost rates among institutions because of the variations in their accounting systems, geographical location, research orientation, age of physical plant and other differences. Third, universities argue that, despite charges to the contrary, they do have significant incentives to contain indirect costs, inasmuch as the government reimburses only that portion of indirect costs that can be attributed to government-sponsored research activities, e.g., part of library costs. Universities have always had to bear a portion of these indirect costs. Also, there is constant pressure from the research faculty to keep the ICR rate down, particularly from those faculty members whose support is administered under the NSF mechanism (see later discussion on NSF and NIH mechanisms for ICR reimbursement). Finally, the universities argue that they do not even claim many legitimate costs of federally sponsored research and that being forced to bear a greater share of those costs only diverts scarce resources from other worthwhile campus activities, many of which contribute to the overall strength of the research and education enterprise.

As university research activities grow in scope, university officials increasingly point to the fact that such costs as fund raising, the bridging of investigators or research groups between externally supported projects and the provision of seed support required to initiate entirely new research activities (in industry federal IR&D allowances provide this support) are not allowed as components of indirect costs even though they play important roles in maintaining and improving the health and vitality of the overall university research activity. These costs too must be covered by institution resources.

The controversy over direct and indirect costs focuses on two issues fundamental to any understanding between the universities and the federal government. First, which costs should be considered reasonable and necessary to the conduct of sponsored research? Second, what share of those costs should the government bear? Mutually agreed upon answers to these questions will remove a major impediment to a smoothly operating relationship between the government and the universities.

TABLE 3
INDIRECT COST REIMBURSEMENT RATES
AS A PERCENT OF DIRECT COSTS
FISCAL YEAR 1985

INSTITUTION	ICR RATE
Johns Hopkins	64.0
Univ. of California, San Francisco	30.6
Harvard Medical School	99.0
Harvard University Areas	62.4
Yale	68.0
Stanford	69.0
Columbia	74.1
University of Washington	40.0
Univ. of California, Los Angeles	43.0
University of Pennsylvania	64.0
Washington, St. Louis	51.0
Yeshiva	87.5
University of Michigan	50.0
University of Wisconsin-Madison	43.0
University of Minnesota	41.0
Duke University	50.0
Univ. of California, San Diego	36.5
University of Chicago	69.0
Cornell University	63.3
Cornell University Medical College	46.0
MIT	61.5
Univ. of California, Berkeley	44.0
National Average	49.3

4. Indirect Costs

There has been almost no controversy over the reasonableness and necessity of direct costs; there has been much over the reasonableness and necessity of indirect ones. This imbalance both reflects and perpetuates the misperception that direct costs are somehow inherently more legitimate than indirect ones. In fact, both are real costs of research. A possible explanation for the differing perceptions may lie in the fact that in contrast to indirect costs, direct ones are universally subject to peer review and judged qualitatively in those reviews for their reasonableness and necessity. This process is accepted as legitimate by the federal government, the universities and the investigators. The assessments made by peer review individuals and panels as to how reasonable and necessary a research budget is are generally viewed as sound and credible.

Government reviews and audits provide scrutiny of indirect costs just as peer review does of direct costs. Federal indirect costs negotiators make on-site reviews of all indirect cost proposals before the ICR rates are negotiated, and some proposals are subjected to a full audit. These reviews focus on whether the proposed costs are allowable and relevant to the performance of research and on whether the institution's apportionment methods result in an equitable allocation of costs to research programs. Because these indirect costs relate to the institution's overall operations rather than to specific research projects, such reviews cannot—and do not—make an assessment as to the reasonableness of the institution's proposed indirect cost charges and allocations.

5. The Documentation Problem

A further form the controversy assumes is over costs that are inherently difficult to quantify or justify. In an attempt to ensure that federal research dollars are being spent properly, the government has increasingly required documentation of research costs. Predictably, requirements to document costs are greatest where documentation is most difficult. In effect, the government attempts to legitimatize through paperwork research costs that are difficult, if not impossible, to justify through other methods. This does not mean that such costs are inherently unreasonable, only that it is difficult to prove otherwise. In general, the government requires documentation on costs associated with federal research as well as on some that are not. In attempting to ensure that it is reimbursing the actual agreed costs of doing federally funded research, the government has imposed layers of documentation and administration requirements upon the universities. Such inefficiency and micromanagement is a natural corollary of a research funding policy based on the procurement approach (i.e. pay for whatever is needed, as it is needed). From the faculty member's perspective, the worst example of such red tape is, of course, faculty effort reporting. A workshop on effort reporting was conducted by the National Academy of Sciences; referring to faculty effort reporting, its members concluded that:

> . . . the basic problem is that the requirements have been patterned largely after industrial practice—regular, after-the-fact reporting of time and effort expended. Such a scheme is not transferable to a university. Effort reporting forms call on faculty members to allot their time among a number of discrete functions. Most faculty effort, however, serves several ends at once and cannot be distributed rationally among discrete functions. An investigator working with a graduate student on a research project, for example, simply cannot divide such effort neatly into research and teaching.

By setting faculty, university administrators and government agencies against one another, faculty effort reporting works against the development of teamwork and of any sense of partnership in the enterprise. The reporting requirements serve to perpetuate controversy over costs that are inherently subjective and impossible to quantify, as well as creating animosity over the unproductive paperwork involved.

There are many other paperwork requirements which are equally inefficient and which serve to inhibit a healthy relationship between the universities and the government. The federal government, for example, now requires inventories of all research equipment owned by an institution, no matter how acquired, in order to compute use allowances. The government also requires exhaustive project-by-project documentation of research subcontracts to small businesses. Such requirements, even when laudable in original principle, work against the goal of efficient research.

None of the present documentation requirements promotes any greater consensus over what constitutes the reasonable and necessary costs of research. In addition to the damage they do to the university-government relationship, these requirements also obviously increase the administrative costs of federally sponsored research.

6. Micromanagement of University Research

In addition, other requirements imposed by the federal government limit the flexibility afforded researchers in the management of their federal grants or contracts. In some agencies, the period of grants is as little as two years, and many must be reviewed annually. Renewal involves preparation of detailed accounts of both past and future work, and invites concomitant scrutiny and micromanagement by peer review panels and agency program officers. Researchers are rarely permitted to carry over unexpended contract funds from one year to the next. Equipment purchases over $5,000 must be cleared through a local screening process, allegedly to prevent duplication. And perhaps most important of all, principal investigators, who are best able to judge the internal priorities of their research programs, are in some instances unable to transfer funding, for example, from other aspects of their programs to the support of graduate students and professional travel, without the explicit and time-consuming approval of agency program officers. The government, reacting in part to the controversy over the cost of research, has sought to increase accountability by imposing counterproductive regulations which impede flexibility, creativity and efficiency in university research.

The universities, in turn, have had little choice but to adopt a short-range belt-tightening view and, in consequence, have

done little to either mitigate the government's distrust or increase the flexibility of the enterprise in the face of government red tape. Their accounting systems are often arcane and antiquated, lending credence to the impression that they are not able to account for their costs. They have seldom initiated alternative organization structures, such as cross-disciplinary centers or block grants to groups of researchers, which might increase flexibility even despite federal regulatory limitations.

7. Mandatory Cost Sharing

Faced with the desire to reduce their research cost reimbursements to universities, Congress has decreed that for some agencies (e.g. NIH), the government should simply not bear all the costs of federally sponsored university research. Based on the concept that universities would be more determined to contain research costs if they are obliged to pay a portion of them, mandatory cost sharing was introduced as an incentive for the universities to be efficient in their management of the federal funds provided.

Despite the lack of any consensus underlying the policy, the government has applied this cost-sharing principle in other areas as well. In 1983, NIH indirect cost reimbursements appeared to be exceeding NIH's budgets. As a short-term solution, the agency attempted to reduce its indirect cost reimbursements by 10 percent across-the-board. It made no determination that the reimbursement claims exceeded the reasonable and necessary costs; the implication was simply that NIH would not agree to pay more than 90 percent of the costs claimed. This attempt failed because of active lobbying by the research community. Continuing dissatisfaction with the perceived shortcomings of the indirect cost reimbursement procedures ensure that the issue will not disappear. Other, more drastic proposals, such as an indirect cost reimbursement based on a fixed 25 percent of direct costs, have recently been considered seriously by OMB.

8. Indirect Cost Reimbursement

There is a final issue—the ways in which indirect costs are determined and reimbursement policies put into practice. Federal agencies which sponsor university research currently employ two somewhat different methods for calculating research cost reimbursements. Both are based on OMB Circular A-21. At NIH, which funds half of the federally sponsored university research, research proposals include only the direct project costs. Peer review panels then consider only the direct portion of the budget; if an award is granted, the institution's current indirect cost reimbursement rate is applied automatically by the agency. In multi-year grants, should this rate rise during the term of the grant, the indirect cost reimbursement rises accordingly.

At NSF, and all other major federal research agencies, reimbursement practices are similar, but their effect is in practice somewhat different. At these agencies, research project budgets include the total proposed costs—the direct cost components (as in the NIH practice) plus the indirect cost reimbursement. Prior to an award, the total cost is negotiated by the principal program officer on behalf of the agency and by the principal investigator on behalf of the institution. Under this system, since the total is usually, but not necessarily, fixed over time, if the indirect cost rate increases, the direct cost reimbursement—those funds available to the researcher—is reduced.

The practical and political differences between the two systems are noteworthy. Both systems are subject to the same institution-by-institution indirect cost rates negotiated by DOD or HHS on behalf of all federal agencies. But the NIH system tends to be more closely associated with the "indirect cost problem" than does the NSF system. When the GAO undertook to study the "reasonableness of rising indirect costs," it was NIH that was the focus of the study. And statistics show greater growth in NIH reimbursements for indirect costs than in comparable NSF reimbursements. In 1966 when the government removed the 20 percent fixed rate on indirect costs, the ratio of indirect to total cost reimbursements was the same (20 percent) at both NIH and NSF (See Appendix G). By 1981, that ratio was 30 percent at NIH, but only 25 percent at NSF. And whereas NIH's ratio continues to grow, NSF's has remained relatively constant.

Another reason why NIH has been more often associated with the "indirect cost problem" is that its system subjects fewer cost components to internal pressures within a given institution than does the NSF system. In the NIH system, the researcher is concerned only with the direct costs of research, and indirect costs are the concern of a university administration negotiator and the negotiator at HHS or DOD. In the NSF system, the researcher sees each dollar of increased indirect cost recovery subtracted directly from the amount available for research; it is thus an issue between the investigator and his university's administration. In the former, the researcher argues with Washington; in the latter, with university administration colleagues. In the NIH system the pressure is on government agencies to balance rising costs against fiscal limitations; in the NSF system the pressure is on the universities. In the NSF system, therefore, faculty are likely to be immediately aware of, and thus bring pressure to minimize, actual indirect costs, thereby working to keep ICR rates down.

Finally, and perhaps most important of all, is the way in which the two systems affect the indirect cost controversy. The NSF system is more likely than the NIH system to be accused of incomplete reimbursement, since the agencies do not adjust the total amount of a grant to absorb possible increases in the applicable ICR rate during the term of the grant. Conversely, it is less likely to be accused of reimbursing for more than the reasonable and necessary costs of research, since the NSF system encourages faculty and university administrators to debate the indirect costs.

Several conclusions can be drawn from this analysis. First, since there has been almost no controversy over direct costs, one can conclude confidently that the peer review system is a sound, credible and effective mechanism for distinguishing reasonable and necessary costs from unreasonable and unnecessary ones. Second, because faculty pressure works to minimize indirect costs, the Panel believes that the NSF reimbursement system is preferable to the NIH one and that no obvious benefits accrue from the present dual system. **We therefore recommend that all federal agencies supporting university-based research**

take steps to adopt the NSF practice for indirect cost reimbursement.

This should not become an invitation to NIH study sections to micromanage the details of project budgets. The members are not likely to be well informed about the structure of indirect costs, nor about the negotiations and audits in which each institution engages with the government. The project review staff at NIH can be appropriately educated and may then be able to guide the peer review mechanisms in ways consistent with the agency's policy. There is no reason, however, for total project costs (including indirect) to be concealed from the review process.

9. Conclusions

The attempts to define precisely the costs of research at universities have resulted in excess of paperwork that is self-defeating, and a constant source of stress between government managers, faculty, and university administrators. As an example, the mandatory cost-sharing concept has generated paperwork and consumed resources, but has resulted in nothing of value. It should be recognized that support of personnel, support of students, and the provision of an environment conducive to the conduct of research and training, in themselves constitute cost sharing. Documentation neither adds to nor subtracts from this.

Similarly, the need for faculty effort reporting results in a totally artificial separation of the multiple overlapping responsibilities of university faculty members. Since the active research effort is also a training function, since a single laboratory may have several related grants, since participation in university and departmental governance also involves administrative functions related to management of federally supported research, and, particularly, since no faculty member works as little as forty hours a week, the formal effort reporting requirements are simply administrative fictions.

These examples are perhaps the most striking, but by no means the only, manifestations of what can only be called bureaucratic accretion. Although the need for accountability which spawned these procedures is understandable, the outcome is, on balance, counterproductive to the goals of all involved. Some attempt at simplification is desperately required.

The indirect cost issue has caused similar, and perhaps even more severe, problems. In summary, indirect costs can be divided into infrastructure and administrative costs. Virtually all the controversy centers on the administrative costs and, in particular, the apparently puzzling variation in rates from institution to institution. As described in Appendix F, there is justification for this diversity. However, the effort reporting, the bureaucratic burdens, the increasing divisiveness, and the damage done to the university-government partnership that flows from the present continuing institution-by-institution negotiation of indirect costs cannot be justified.

In conclusion, the Panel strongly recommends that the federal government agree to bear its full share of the cost of university-based federally supported research. This would entail an understanding that cost sharing is inherent in the resources that universities bring to the research effort. In order to ease the stresses resulting from negotiated indirect costs, a single level for the administrative component of indirect costs should be established. In parallel, a reduction should be made in the unnecessary and overly burdensome paperwork associated with grants and contract management; elimination of the effort reporting that will follow from our recommendation for the fixing of the administrative component of the indirect cost pool will, in itself, go a long way toward reducing the friction in the government-university interface and the real level of indirect cost.

10. Recommendations

1. The federal government should bear its full share of the cost of university research it supports.
2. Reimbursements for administrative costs within the indirect cost category should be fixed at a uniform percentage of modified total direct costs. That percentage should be the mean percentage over a five-year historical period, and the adjustments should be phased in over a two-year period to allow those universities now charging more than the new fixed rate to plan for reduction. This change will eliminate much of the need for faculty effort reporting.
3. The formal requirement for cost sharing should be eliminated.
4. The paperwork burden associated with grant and contract administration should be reduced to a minimum. In the Panel view, all faculty effort reporting should be eliminated.
5. All federal agencies supporting university research should adopt the NSF practice of including the indirect costs in the project budget subject to peer review.

The Panel recognizes that some universities will face reduced indirect cost reimbursements if our recommendation concerning administrative costs is implemented. We emphasize, however, that our recommendations concerning more realistic use allowances for facilities and equipment are designed, in part, to offset such reductions. It is therefore of special importance that our recommendations be considered as an integrated package; were they to be only partially or selectively implemented, they could result in significant damage to the academic enterprise.

V. THE ENVIRONMENT FOR ACADEMIC RESEARCH AND EDUCATION

There is only one proved method of assisting the advancement of pure science—that of picking men of genius, backing them heavily, and leaving them to direct themselves.

James Bryant Conant
Letter to The New York Times
August 13, 1945

1. Introduction

The U.S. university system is based on the fundamental conviction that the discovery of new knowledge and the education and training of new scientists and engineers are inseparable activities. Students learn to be scientists and engineers by doing science and engineering. Faculty members depend on the creativity and fresh approaches of students to challenge accepted paradigms and inject vigor and originality into the research effort. Without a sufficient flow of well prepared and motivated students entering the university system, our national scientific and technological enterprise will founder. This serious national problem—characterized in *A Nation at Risk*, the report of the National Commission on Excellence in Education, as "a rising tide of mediocrity"—has been well studied elsewhere, and significant corrective measures are under way.

Central to the production of both talent and new knowledge are university faculty members; they teach students and direct research, usually simultaneously. The quality of the faculty determines how well the universities are able to respond to the Nation's demands for this talent and new knowledge. And the effectiveness of faculty members depends on the environment in which they function—what we call the academic research environment.

This environment has many components: research facilities and equipment, university administration, federal funding agencies, professional peers, industry connections, support personnel and students. In a healthy university, these components promote excellence, imagination and responsiveness in the development of both talent and new knowledge. Creating such an environment requires the best efforts of industry, government and the universities. We address a variety of issues that affect the creation of such an environment.

2. Stability of Research Support

Stability of research support means that research projects are not unexpectedly interrupted. If federal funding to an individual investigator is interrupted, it can bring the research project to an unexpected halt, seriously interrupt the progress of the graduate students involved, force reassignment of equipment and space to other projects, and place into question the professional fate of the technical staff involved. Fluctuations in federal research funding can greatly interfere with the training of graduate students. If funding for a project is interrupted or discontinued, it means inconvenience and wasted time and effort for the principal investigator. But for the student, it can mean several years of graduate school wasted and for some, a comprehensive reassessment and restructuring of their entire dissertation program.

Central to the maintenance of stability is the ability of individual institutions, through fungible cash reserves, to provide flexibility of funding in the event of unexpected fluctuations in federal support. Such a capability depends both on responsible financial management by the universities and on enlightened actions by both government and industry in making it possible for the universities, already hard-pressed financially, to establish the modest reserves necessary to permit their performance of this flywheel function.

3. Optimizing the Funding Process

Most important, however, is the means by which federal funds are allocated. The U.S. is unique in the extent to which responsibility for the allocation of federal dollars to scientific research is largely in the hands of the scientific community itself. This is an arrangement forged by enlightened representatives of both the federal government and the scientific community in the immediate postwar period; it has allowed this country to evolve a science and technology enterprise that is the envy of the world. The peer review system on which this arrangement is based has served the nation extremely well and must clearly be preserved; but at the same time, over the years a few difficulties have developed.

a. The Peer Review Process

In the peer review system, an investigator's research proposal is reviewed by a panel of professional peers who score the proposal, theoretically on the basis of its scientific merit. That score may reflect, to some degree, the reviewer's assessment of the investigator, but the principal emphasis has been on the proposal as such. Each agency, in general, ranks its proposals by score and awards grants in order of descending score until its budget for the year is exhausted.

The system of awarding grants and contracts on the basis of peer review is essential to our ability to maintain excellence in science. But we have noted the tendency, over the past decade, to focus more upon the specific research proposed and less upon the track record of the proposing investigator. Applied to an endeavor such as basic research—a foray into the unknown and unpredictable—this trend can be counterproductive. The skills needed by a successful and creative researcher are above all those for improvisation in the face of unexpected discoveries or disappointments. A carefully conceived proposal can never substitute for proven and sustained accomplishment—especially in the case of research of a frontier or exploratory character. And yet, proposals by established, reputable scientists continue to be rejected by peer groups and agencies on the grounds that the reviewers perceive insufficient chance of success, inadequate preparation or insufficiently precise anticipation of results. As one researcher told us:

> Unfortunately, it is not an exaggeration to say that the agencies expect a proposal to outline the anticipated discoveries. . . To require that the solutions to all problems be obvious before the research is begun discriminates strongly against innovative work.

Indeed, the peer review system has, at times, been antagonistic toward creativity, and examples exist of truly creative and revolutionary research that has been conducted in recent years only in spite of obstacles inherent in the peer review process.

In the course of our study, we have also heard testimony, which we find persuasive, that the present peer review process frequently makes it difficult for researchers to change fields. Many highly competent scientists have been discouraged from moving to possibly more productive and challenging fields by the knowledge that if they remain in their established ones they are reasonably assured of a steady flow of federal support; while if they attempt to move, they may face a much more uncertain future with new peer reviewers.

b. Structure of Grants and Contracts

A further serious problem in federal support of university research is the short duration of typical awards. Many NSF grants, for example, are made for only two years; DOD and DOE grants and contracts typically require renewal on an annual basis. As a result, investigators—and particularly young investigators—frequently spend 20 percent to 30 percent of their time and energy in sustaining the flow of their research support. Because these periods are so short, there is always the temptation on the part of peer review scientists to attempt to micromanage the research of their colleagues, requiring modifications of proposals both at the outset and during renewal of support. And because the short periods necessitate so many reviews, the peer review system itself at times becomes overwhelmed. It is not unusual for a two-year grant request to require a year between submission and approval. If a peer review panel finds difficulties with a proposal, the funding cycle is often so far advanced that a revised proposal may be delayed until the following year. In the case of new proposals, this can simply mean a year of wasted time; in the case of renewals, it means disruption of the work already in progress.

In many cases, then, the peer review system imposes significant and time-consuming paperwork burdens. The challenge is one of retaining the truly essential quality control aspects of the peer review process while minimizing the associated bureaucracy and conservatism.

Beyond the peer review stage, there are other barriers which limit the ability of researchers to direct optimally his or her efforts. For example, the difficulty in redirecting grant and contract funds when new opportunities arise is one handicap, as is the inability to carry forward unexpended funds from one year to the next.

We particularly recommend that agencies make greater use of block grants or contracts which permit groups of interested researchers to band together in pursuing common research interests. This approach allows groups of researchers to leverage their funds in pursuing their objectives. This can also have important advantages in terms of continuity, development of highly qualified and long-term support groups, establishment of instrumentation and equipment beyond the range of any single investigator or funding instrument, maintenance of that equipment by fully qualified personnel and, perhaps most important, the freeing of younger participating scientists from the time and energy consuming bureaucracy involved in acquiring facilities, instrumentation and support at a time when their creative powers are at their peak.

4. Student Support and Education

The heart of the university research system is the parallel education of students. In view of the disproportionate leadership demands that a democratic society such as ours makes on its most able citizens, it is in the national interest that these individuals be identified and adequately supported at an early point in their careers so that they can develop their skills to the fullest. No nation can long afford to waste even a small fraction of its most able youth. It is important to recognize that many of these individuals are ineligible for the support, under current programs, that would enable them to attend the institutions of their choice.

It is important to emphasize that the most able students in mathematics, engineering, and the natural sciences be enabled to develop their intellectual potential and creativity. We are confident that this is in the national interest; it is the most effective investment that any nation can make in its future. It is an essential contribution to ensuring that there is an appropriate pool of well-educated, interested, and dedicated young people from which our graduate schools can draw.

a. Undergraduate Scholarships

We emphasize our recommendation that this support to undergraduate students be provided through programs of competitive merit-based scholarships. All these at the undergraduate level should be portable in the sense that, once awarded, the successful student should be entirely free to hold the scholarship at the institution of his or her choice. In addition to supporting our most able youth, such a program has the great advantage of providing a powerful incentive to the receiving colleges or universities to evolve education programs of particular interest and attraction to the most able students.

We recommend that as a national goal 1 percent of the most able undergraduate students in mathematics, engineering and the natural sciences entering colleges and universities each year be supported under these programs. In 1983, some 196,923 students received their baccalaureate degrees in engineering, mathematics and natural science. If we take this as a basis for estimation and assume that 1 percent of the entering students receive four-year scholarship support at the level of $15,000 per year, the annual program cost is roughly $120 million. We consider this to be perhaps the single wisest investment that we, as a Nation, could make.

It is sobering to recognize, too, that statistics on the student populations already in the precollege pipeline show that in the early 1990's the annual number of baccalaureate degrees awarded will be close to 150,000 rather than approximately 200,000 as in 1983. These are the data that underlie current NSF projections of very serious shortages of engineers and scientists in the 1990's.

It must also be emphasized that the merit-based scholarship programs that we recommend are certainly not intended in any way to replace the current need-based programs that have given access to higher education to a wide spectrum of students to whom it would otherwise have been denied—as well as making our universities and colleges more interesting and effective institutions.

b. Graduate Fellowships

At the graduate level, a portion of the awards should be reserved for fellowships for study at designated institutions in order to take advantage of special programs or facilities or in order to emphasize areas where special national needs may become evident.

As shown in Figure 9, the percentage of foreign students receiving doctorates in a number of fields—but most especially engineering—has been increasing in striking fashion in recent years. It must be emphasized, however, that this trend does not reflect any greatly increased flow of foreign students into our graduate schools but rather a marked decrease in the number of U.S. students who, in the face of other opportunities, are choosing to continue their education at the graduate level.

The current shortage of U.S. graduate students in engineering, mathematics, and physical sciences is being offset partially by foreign students in U.S. universities. The trends are a very persuasive endorsement of the quality of U.S. graduate education in engineering, mathematics, and the natural sciences as viewed from other countries, but they also indicate the need to provide incentives for U.S. students to continue their education in these critical areas.

5. The Universities and Industry

Because industry is the ultimate customer of a large fraction of the scientific and technical talent and the new knowledge produced by the universities, industry's wisdom and influence, quite apart from its financial support, are essential inputs to the university research environment. In recent years, substantial progress has been made toward rebuilding the industry-university bridges that were largely destroyed during the period of rapid growth in federal support of university activities in the 1950's and 1960's; much remains to be accomplished in this vital interface, if a true industry-university partnership is to be established in this country.

As noted in Chapter III, industrial involvement with universities is increasing through a variety of mechanisms. In addition to these varied forms of research interactions, it must be recognized that the prime motivation for overall industry support of the health and activity of U.S. universities is the continuing demand for trained scientists, engineers and other graduates. The technological revolution not only makes heavy demands for new young scientists, mathematicians, and engineers in the marketplace, but also focuses increasing attention on the crucial need for effective continuing education.

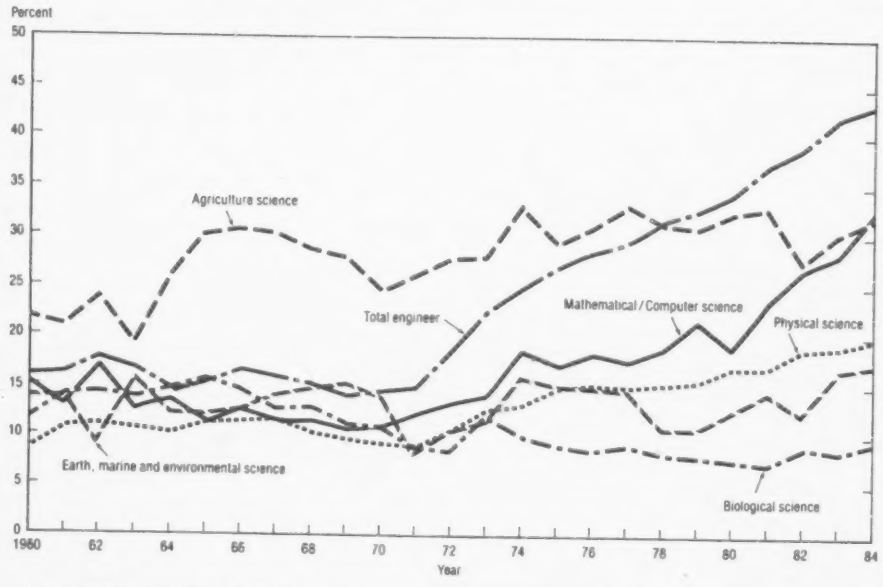
Not too long ago it was widely assumed that the educational phase of one's life was over after the completion of a formal university training and that it was time to move on to the real world, applying that education. But the increasingly rapid pace of technological change has made such a view totally unacceptable—if indeed, it ever was acceptable. Obsolescence of engineering and scientific skills is becoming ever more rapid, and in their own self-interest, industries must work with universities to develop and support new mechanisms and programs whereby university resources of faculties and facilities can be made more available to older scientists and engineers who recognize the necessity of renewing and modernizing their expertise or who may wish to make a major change in their career path. Universities and industries should work together to provide effective life-long educational opportunities for employees and technical people generally.

As noted earlier in this report, the current U.S. competitive position in defense, trade, and health is strongly coupled to earlier investments in science and technology. We are now being challenged to remain competitive in those very areas of science and technology where our preeminence was once unquestioned. To respond to this challenge we must reestablish those links between industrial innovation and academic science that were in the past the catalysts of U.S. industrial technologies.

And this must be done with the recognition that the problems to be addressed have burst the conventional disciplinary boundaries. The basic research that will be necessary to fuel our economy in the future will require interactions across disciplines and with the active collaboration of many groups having different perspectives and training.

Figure 9

Percent of national science and engineering doctoral degrees received by non-resident foreigners, selected disciplines: 1960–1984



SOURCE: "Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook." Prepared by National Science Foundation, Directorate for Scientific, Technological, and International Affairs, Division of Science Resources Studies, Table B-21.

It is our conviction that the multidisciplinary centers (discussed earlier) based on these premises will allow a flexible response to new opportunities, give industry a window into the campus environment, and will pay back the public investment manyfold. Such programs offer a student who has a firm grounding in one of the established disciplines at the undergraduate level an opportunity to contribute his expertise as an effective partner in a multidisciplinary program at the graduate level that truly draws on the insights and intellectual resources of all the relevant disciplines. Such centers can provide a focus for faculty members who straddle traditional departmental boundaries and for whom universities often find it difficult to establish long-term positions.

6. The Universities and the Federal Laboratories

Increased interaction between the federal laboratories and the universities should be encouraged. The Panel fully supports the recommendation in the White House Science Council Report on Federal Laboratories that these laboratories should encourage much more access to their facilities by both universities and industry. Exchange programs that provide opportunities for faculty and graduate students to work in the laboratories and for laboratory scientists to teach in the universities and colleges should be enhanced. The value of increased involvement of university scientists and administrators as advisors to laboratory programs was also noted in the Energy Research Advisory Board Report on the Relationships between DOE and the Universities. The potential for existing federal laboratories to play a complementary role to the universities in both research and training should be further developed.

7. Role of State Governments

Like industry and the federal laboratories, communities benefit substantially from being located near strong universities. Silicon Valley in California, Route 128 in Massachusetts, Research Triangle Park in North Carolina, and similar developments in Austin, Texas, are well-known examples. State governments have a responsibility to help shape and develop local universities to meet regional needs and characteristics. Particularly with respect to state universities but also for private universities, states can have a profound effect on the quality of institutions by augmenting federal research programs in areas of

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particular regional interest (i.e., agriculture, seismology, metallurgy) by providing infrastructure support and unrestricted grants to institutions, to groups of researchers or to individual faculty members and by becoming actively involved in the education process. Perhaps most significant, the state governments can work with local universities and industry to improve pre-college education in science and mathematics, creating ripple effects throughout the entire education system.

8. Conclusions

The combination and balance of factors that create an effective environment for academic research and training are complex and largely undefinable. The Panel has attempted to identify several issues that have a significant effect on the way research and training is conducted at universities, and where beneficial changes can be made.

It is clear to us that the short duration of grants at many federal agencies provides paperwork barriers and fiscal uncertainty for the investigator that far outweighs any advantage to be gained by more frequent monitoring of research progress.

An important initiative that we recommend to increase the effectiveness of the academic research environment is the increase in duration of most federal grants to at least three and preferably five years. This would increase not only stability but also effectiveness in reducing the number of renewals and the amount of reporting paperwork required in a given period of time. During the past year, NIH has already taken important steps to lengthen the periods of their grant commitments. We applaud this initiative and encourage other agencies to follow suit.

A related issue is the liberalization of policy so that investigators can make the most effective use of their funds. To increase stability and flexibility in the use of research funds, we recommend that successful investigators should be allowed to use 10 percent of their grant or contract funding on a discretionary basis; further, they should be allowed to carry forward unexpended funds in their grants or contracts from one fiscal year to the next.

As a final point in this area, we recommend that agencies should make much greater use of block grants or contracts which permit groups of interested researchers to band together in pursuing common research interests.

We would encourage the peer review group to focus less on the predictability of success implied in a proposal, and more on the track record of the investigator.

Together with research, the major mission of the university is the training of young minds. It is the view of the Panel that a vital element of national well-being depends on the opportunities provided to its most able citizens, regardless of economic or social class. Perhaps the most important guarantee that these opportunities will exist, is appropriate education and training.

We recommend, therefore, the establishment of substantial programs of merit-based, portable, federally supported scholarships and fellowships in mathematics, engineering, and the natural sciences at the undergraduate level. We further recommend that parallel programs in industry be established at the initiative of individual companies. It is essential that, at the undergraduate level, all these scholarships should be portable in the sense that once awarded, the student be allowed complete freedom to select the university or college in which the award is to be held.

We recommend that the Nation should accept as a goal the provision of merit-based support for the most able 1 percent of our students in mathematics, engineering, and the natural sciences entering colleges or universities each year. We are convinced that this will represent the most effective investment that this Nation can make in its future. Substantial programs of multiyear merit-based fellowships, both federal and industrial, should also be estabished in science, mathematics, and engineering at the graduate level. Reflecting broad national needs, the field distribution of these fellowships likely would change over time. At the graduate level, we recognize that it will be desirable to have a substantial fraction of the awards nonportable in the sense that they are attached to a particular institution, facility or program to reflect perceived national needs.

In order to insure that students can be sufficiently trained to cope with the changing boundaries of research, we recommend that more emphasis in universities be placed on the development of interdisciplinary programs at the graduate and postdoctoral level. Universities offer a unique environment where not only scientific and technological expertise but also that from the social, behavioral and economic sciences as well as the humanities can be brought to bear on problems of major importance.

We note that industries and universities have a common need and responsibility to develop attractive continuing education mechanisms and programs for engineers and scientists that are matched to contemporary industrial requirements and to modern science and technology.

9. Recommendations

1. Federal agencies should work toward an average research grant or contract duration at universities for at least three, and preferably five, years.

2. Investigators should be free to use up to 10 percent of their grant or contract support on a fully discretionary basis and should be permitted to carry unexpended funds forward from one fiscal year to the next.

3. Federal agencies should make much greater use of block grants or contracts in support of groups of investigators having shared research interests.

4. For greater flexibility, to facilitate changes in an investigator's field of research, and to support high-risk research, federal support agencies should, except in the cases of young investigators, place substantially more emphasis upon the research history of the investigator and less on the proposed research project in making awards.

5. A substantial program of merit-based, portable scholarships should be established by the federal government at the undergraduate level. Parallel programs should be established by all industries having significant dependence upon university research and education. The national goal should be for the most able 1 percent of the undergraduate

students in mathematics, engineering, and the natural sciences entering colleges or universities each year to be supported under these programs. This program is recommended as an addition to, not a substitution for, existing need-based federal assistance programs.

6. Substantial programs of multi-year merit-based fellowships, both federal and industrial, should be established in science, mathematics, and engineering at the graduate level. Reflecting national needs, the field distribution of these fellowships would be expected to change over time.

7. Universities should encourage interdisciplinary activities at the graduate level while retaining the essential quality control function now played by the traditional disciplinary departments.

8. Industries and universities should develop attractive continuing education programs for engineers and scientists that are matched to contemporary industrial requirements and to modern science and technology.

VI. Summary

For most of this country's history, basic research was largely neglected, and came predominately from Europe. Federal involvement in universities was primarily in applied areas such as agriculture and engineering. Industry also had limited interaction with universities, and again essentially in applied fields. For the past 40 years, the major elements in the evolution of university-based research has been the relative weakening of the university-industry connection and the strengthening of the university-federal government interaction. (Note that a three-way "partnership" has never had more than a transient and limited existence.) In parallel with these changes has come a growing recognition of the importance of basic research in serving the needs of society, and of the importance of the universities in this endeavor.

The federal government's relationship with the universities has always been based on the premise that university activities are fundamental to meeting society's needs. Over a century ago, the Nation's dependence upon the agricultural economy stimulated establishment of the land-grant colleges, whose research and training helped make American farmers the most productive on earth. Today, we depend on technology for our competitive edge in virtually every area of our economy. Our investments in university education and research, and thus in new scientific knowledge and talent, are therefore even more important. To carry out this mission, it is essential that the major participants in the research enterprise, government, industry, and universities, clearly define their roles and responsibilities in the partnership.

It must be recognized, however, that university-based research has, in the modern era, been 70 percent supported by federal funds and that more than 60 percent of the basic research performed in this country is conducted at universities. The long-range nature of basic research, and the absence of any predictable payoff, effectively precludes significant investment from industry. Furthermore, the scope of university-based research is far too great to be supported through internal resources alone. Consequently, it is the federal contribution that will determine the rate of growth of the system. Perhaps even more important than the level of funding, however, is the need for stability and predictability of scope and support from federal funding. They are essential to the effective use of financial and human resources. In the past, such stability has been sadly lacking. In its absence, important opportunities have been lost, resources have been used in less than optimum fashion, and, most serious of all, some of the brightest young minds have been lost to science and technology.

The interaction of industry with the universities is essential to provide an effective exploitation of the research base. This partnership is critical to our national well-being in an increasingly competitive world marketplace. Particularly important is the assistance industry can give in understanding the translation of basic research to technology development. As noted earlier, the nature of these interactions are as important as the direct financial contributions which industry may make to the support of research.

The Panel has attempted to identify some specific problems, and has made specific recommendations that bear on the health of the universities. **Independent of the scenarios that the Panel has considered, one clear fact emerges. Within the context of probable future growth, hard choices lie ahead for universities. It will not be possible to accomplish all the things that would be in the national interest in the near future; it may well be impossible to accomplish all of them even in the long term.** It is the responsibility of each university to make the difficult trade-offs among faculties, facilities and programs necessary to maintain its institutional health and vitality within whatever level of external support it may find itself constrained to operate. It is equally the responsibility of all of the participants in the R&D enterprise mutually to establish the goals of federal funding—particularly the questions of stability and growth, enhancement and expansion. Only then can the details be defined in a rational manner.

VII. APPENDICES

A. Charge to the Panel
B. Activities of the Panel
C. Witnesses Who Appeared Before the Panel
D. Panel Questionnaires
E. Correspondents Who Provided Input to the Panel
F. Indirect Costs
G. Summary History of Indirect Costs
H. Numerical Data
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APPENDIX A

THE WHITE HOUSE

WASHINGTON

May 3, 1984

Dear Sol:

As you know, our nation's ability to compete successfully both in the military and industrial arenas will depend a great deal on the continued creation of knowledge and an adequate supply of scientific and technical talent. The support of basic research and the production of such talent are major objectives of the Administration's science and technology policy. The continuing health of our nation's universities is fundamental to this policy. Although our universities and colleges are now the best in the world, I am concerned that lack of agreement on a number of long-standing problems could affect their health and vitality. These problems have been documented in numerous recent studies. They directly affect the ability of the universities to attract and retain the best minds both to do research, and to teach and learn, in science, engineering and medicine.

I would appreciate it if the WHSC would examine and make necessary recommendations for revising the principles underlying the relationships between the Federal government and the universities, especially as they affect the U.S. ability to create the scientific and technical talent and to conduct the research needed to sustain America's leadership in industry and defense. The Council should provide a tautly reasoned policy statement, which would serve to guide Federal actions with respect to universities and colleges.

My office will coordinate the necessary staff support, resources and administrative arrangements for your effort.

Yours truly,

G. A. Keyworth
Science Advisor to the President

Dr. Solomon J. Buchsbaum
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APPENDIX B

ACTIVITIES OF THE WHSC PANEL ON THE HEALTH OF U.S. COLLEGES AND UNIVERSITIES

The Panel was established by the White House Science Council, at the request of Dr. George A. Keyworth, former Science Advisor to the President.

Its initial organizational meeting was held in Washington on May 17, 1984. Subsequently, the Panel held eight additional one-day and two two-day meetings. Over the period since May of 1984, a substantial number of working group meetings have been held in Washington, New York and New Haven in order to prepare material for discussion at the plenary sessions held on June 19, August 6-7, September 19-20, October 25, November 29 of 1984; and January 11, February 8, June 7, June 27 and September 28, 1985.

During the meeting on September 19, 1984, the Panel heard from a number of representatives of the academic and scientific communities (see Appendix C), and during that on June 7, 1985, from representatives of the Department of Health and Human Services. During working group sessions, members of the Panel and OSTP staff met with representatives of the Department of Defense, National Science Foundation, Office of Management and Budget, National Institutes of Health, Association of American Universities, National Research Council and the Council on Governmental Relations.

In order to obtain input from as broad a spectrum of opinion and experience as possible, the Panel prepared questionnaires (see Appendix D) which were sent to a sample of university presidents, academic principal investigators, academic administrators, industrial chief executive officers, foundation executives and executives of academic associations.

The list of those who responded to these questionnaires or who volunteered input to the Panel is provided in Appendix E. The insight provided by these correspondents has been of great assistance.

A penultimate draft of this Report was circulated to the Panel members for comment in August of 1985, to members of the White House Science Council and to a very limited number of senior federal administrators who generously agreed to receive the draft on a privileged basis and provide us with their critical comment. The comments received from all of these readers have been most helpful to the Panel.

On September 26, 1985, the Panel held its final meeting at which time the content of the Report was finalized for transmission to the White House Science Council.

Dr. Bernadine Healy, Deputy Director of the Office of Science and Technology Policy, has served as Executive Secretary of the Panel. She and Dr. George Keyworth, Director of OSTP, have been active participants in the Panel activities. We have been most ably supported by Mary Gant and other members of the OSTP staff. The warm thanks of the Panel goes to all of them.

APPENDIX C

WITNESSES APPEARING BEFORE THE PANEL

September 19, 1984

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June 7, 1985

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Gary Talesnik
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APPENDIX D1

QUESTIONS SENT TO UNIVERSITY PRESIDENTS

1. What do you believe to be the major problems, if any, in training new scientific and engineering talent in our universities and colleges? Any solutions?
2. Do you perceive instabilities in the current partnership of government-university sponsored research? If so, what are they?
3. Are there federal policies regarding government research funding that you find unduly burdensome? Any suggestions for change?
4. What in your view is the best way to deal with the rising indirect cost rate for sponsored research? Are there ways that the departmental and sponsored project administration costs, which comprise close to 40 percent of total indirect cost reimbursements, can be reduced?
5. How are you affected by the federal requirement for cost sharing and its documentation? How best should the university and government share the costs of research?
6. What are the risks and benefits of university-industry collaboration with regard to financial interaction or exchange of human capital?
7. What impediments to fruitful research are most often mentioned by researchers? What changes, if any, might alleviate these impediments?
8. What is your assessment of your university's facilities (buildings and equipment) for science and technology? If you have problems with facilities, what aspects, if any, appear to defy resolution without federal government involvement?
9. What steps, if any, could the federal government take to improve the quality of science and engineering education at non-research (i.e., primarily undergraduate) institutions?
10. Do foreign students comprise a substantial portion of your science and technology student body? What advantages and disadvantages do they present?
11. Do you set priorities among areas of science in allocating research resources within your university? If so, how?
12. Are there specific interactions between your institution and the federal R&D agencies that you see as posing difficulties or you would like changed? Do you feel you have a voice within those agencies on issues of funding mechanisms, peer review, etc?

APPENDIX D2

QUESTIONS SENT TO FOUNDATIONS

1. From your perspective, what are the major strengths and weaknesses in the U.S. university system with respect to the training of new scientific talent?
2. Because of escalating costs, problems with facilities, equipment, and faculty shortages in some disciplines, there is concern about the ability of U.S. universities to carry out their research and educational missions in science. In general, what responsibility does the federal government have, if any, to correct the situation?
3. The federal government supports about 66 percent of U.S. basic research. From your perspective, is the present program of support properly distributed among the various areas of science to meet the needs of today's industries?
4. Almost half of the federal funding for basic research goes to roughly 25 top U.S. research universities. Should the government broaden the support and increase the number of top research universities? If so, how?
5. What role, if any, should the federal government assume in providing new or replacement capital for universities in which significant numbers of scientists and engineers are trained? What is industry's role?
6. What are the risks and benefits of industry and university collaboration either with regard to financial interaction or exchange of human capital? Should the government seek to increase research interactions between industry and the universities and, if so, 1) how important is this task and 2) what mechanisms should be employed to accomplish it?
7. Could industry benefit from greater involvement with universities? If so, what factors limit its interaction?
8. What should be the federal policy with regard to admission of foreign students in science and engineering at U.S. universities?
9. How actively does your organization support academic institutions? How many resources, human or fiscal, are involved?
10. Do you think industry is able to attract the number and quality of technical talent to meet its needs?

APPENDIX D3

QUESTIONS SENT TO INDUSTRIAL CHIEF EXECUTIVE OFFICERS

1. From your perspective, what are the major strengths and weaknesses in the U.S. university system with respect to the training of new scientific talent?
2. Because of escalating costs, problems with facilities, equipment, and faculty shortages in some disciplines, there is concern about the ability of U.S. universities to carry out their research and educational missions in science. In general, what responsibility does the federal government have, if any, to correct the situation?
3. The federal government supports about 66 percent of U.S. basic research. From your perspective, is the present program of support properly distributed among the various areas of science to meet the needs of today's employers, especially industry?
4. Almost half of the federal funding for basic research goes to roughly 25 top U.S. research universities. Should the government broaden the support and increase the number of top research universities? If so, how?
5. What role, if any, should the federal government assume in providing new or replacement capital for universities in which significant numbers of scientists and engineers are trained? What is industry's role?
6. What are the risks and benefits of industry and university collaboration either with regard to financial interaction or exchange of human capital? Should the government seek to increase research interactions between industry and the universities and, if so, 1) how important is this task and 2) what mechanisms should be employed to accomplish it?
7. Could your firm benefit from greater involvement with universities? If so, what factors limit your interaction?
8. What should be the federal policy with regard to admission of foreign students in science and engineering at U.S. universities?
9. How actively does your organization support academic institutions? How many resources, human or fiscal, are involved?
10. Is your institution able to attract the number and quality of technical talent to meet your needs? Is this issue a concern in your corporate planning?

APPENDIX D4

QUESTIONS SENT TO PRINCIPAL INVESTIGATORS

1. What do you believe to be the major problems, if any, in training new scientific talent in our universities and colleges? Any solutions?
2. What changes do you think would make a career in university research and teaching more attractive to young PhD's?
3. Are there federal policies regarding government research funding which you find unduly burdensome? Any suggestions for change?
4. What in your view is the best way to deal with the rising indirect cost rate for sponsored research? Are there ways that the departmental and sponsored project administration costs, which comprise close to 40 percent, can be reduced?
5. Should the federal government allocate more funds to institutional or block grants, or to larger multicomponent specialized center grants? What do you view as the relative advantages and disadvantages of individual, block and center funding?
6. Do you have specific concerns about or comments on federal agency grant application mechanisms, funding time periods, the review cycles, or appeals process?
7. Do you see problems with the existing peer review mechanism? How should methodology, quality of ideas, and track record of the investigator be weighed in evaluating a proposal?
8. What is your assessment of your university's facilities (buildings and equipment) for science and technology? If there are problems with facilities, what aspects, if any, appear to defy resolution without federal government involvement?
9. Do you have direct experience with industry supported research? What have been the benefits and costs of such research?
10. Do you have concerns about the number of foreign graduate students in science and engineering? What advantages and disadvantages do they present?

APPENDIX E

CORRESPONDENTS WHO PROVIDED INPUT TO THE PANEL

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APPENDIX F

Indirect Costs

1. The Components of the Indirect Cost Pool

To better understand the controversy, it is helpful to disaggregate the indirect cost category into its component cost pools. Under the present framework established in OMB Circular A-21, indirect costs are divided into the following pools.

Indirect Cost Pool	Average Indirect Cost Reimbursements in 1984
(1) Operation and Maintenance (utilities, janitorial services routine maintenance, etc.)	28%
(2) Use Charges for Buildings and Equipment (or depreciation of institutional assets)	10%
(3) Libraries (books and materials, salaries, expenses and fringe benefits of librarians and library staffs)	4%
(4) Student Administration and Services (costs of registrar, deans of students, student advisors, health services, etc.)	1%
(5) General Administration (salaries, expenses and fringe benefits of university officials and university-wide offices, such as personnel, accounting and payroll)	15%
(6) Sponsored Projects Administration (salaries, expenses and fringe benefits of administrators and staff in offices set up to administer sponsored research programs)	7%
(7) Departmental Administration (salaries, expenses and fringe benefits of personnel [e.g. chairmen, secretaries and faculty] in academic departments and divisions, and organized research units attributable to administration activities)	33%

In essence, these seven pools are actually subdivisions of two types of costs: the first three may be considered infrastructure costs, and together they currently amount to approximately 23 percent of costs, on average. The second four are administrative costs, and together they amount to about 26 percent of direct costs, on average. Together, university indirect costs now constitute, on average, almost one-third of total research costs, or half of direct costs.

2. Infrastructure Costs

There is no universally applicable rule of thumb for determining what are reasonable and necessary costs of infrastructure. Institutions have different expenses according to their age, geographic location, disciplinary specialities, etc. But determining the infrastructure costs at a single given institution is not especially mysterious. The costs are relatively easy to document, and the types of costs do not vary significantly from institution to institution. The controversy over the costs of facilities and equipment, however, does not involve uncertainty as to how they are determined; rather the uncertainty is over whether, or to what extent, they are recognized by all parties as legitimate, reasonable and necessary costs of research. In the last decade and a half, universities and government have been unable to agree on these matters.

In fact, the costs of research facilities and equipment are reasonable and necessary costs of research. Modern research is impossible without modern laboratories, libraries, instruments and computers, and the health of the university system is fundamentally dependent upon the condition of these items in the universities. In order to fund the capital investments necessary for the establishment of such facilities, many universities have undertaken substantial indebtedness through direct borrowing or the issuing of bonds. We have recommended substantial changes in the regulations governing use allowances for facilities and equipment in order to more nearly reflect the actual situation in the universities.

3. Administrative Costs

The controversy over administrative costs is quite simply over which costs should be considered reasonable and necessary. Central to the controversy is the matter of administrative costs. At a time when indirect cost reimbursement rates are rising, many researchers suspect that some of the costs claimed for departmental and sponsored projects administration activities are, in fact, neither reasonable nor necessary. Departmental administration costs are regarded dubiously because they are computed substantially on the basis of faculty effort reporting; sponsored project administration costs are also based in part on effort reports and—in the view of many researchers—reflect a haven for unproductive bureaucrats. By and large, the universities have defended ICR rate increases by pointing to increases in infrastructure cost pools, while researchers and government representatives have complained about ICR rate increases by pointing to administrative cost pools.

In 1983, in its study of the costs of federally funded R&D, the President's Private Sector Survey on Cost Control—the Grace Commission—issued its *Task Force Report on Research and Development*. With respect to administrative costs, the report concludes:

> The administrative components of the indirect cost rate (departmental administration, general and administration, and sponsored project administration) are the most difficult components to establish on the basis of documented, objective evidence and further attempts to reach a compromise on acceptable forms of docu-

mentation will only create more friction and frustration. Instead fixed rates should be negotiated and the ongoing requirements for documentation of actual rates should be eliminated.

It further recommends:

> The cognizant agencies should negotiate indirect cost rates that include a fixed rate for the administrative components and relieve the universities of the main portion of the burden associated with effort reporting.

A report released in March 1984 by the General Accounting Office (GAO) entitled, *Assuring Reasonableness of Rising Indirect Costs on NIH Research Grants—A Difficult Problem*, states:

> Departmental administration expenses are subjective and not easily verified (p. iv), [and notes that such costs] will undoubtedly be the source of continuing controversy. (p. vii)

The Panel finds itself in full agreement with these findings and with the Grace Commission recommendation.

Government representatives, researchers and university administrators all described departmental administration costs in terms similar to those used by the Grace Commission and by GAO. Departmental administration comprises some 30-35 percent of indirect cost reimbursements (60-70 percent of administrative cost reimbursements), the largest fraction of any indirect cost pool and twice as large a fraction as the next largest administrative pool—general administration. While university administrators will generally acknowledge that faculty effort reporting is nonsensical and that departmental administration expenses are thus difficult to justify, they contend, with some argument from the government and the researchers, that reimbursements for the three remaining cost pools (general administration, sponsored projects administration and student services) reflect reasonable and necessary administrative costs.

The next most controversial administrative pool after departmental administration, sponsored project administration, accounts for about 8 percent of indirect cost reimbursement and covers the administrative costs associated with the actual federal grant and contract process. It has two components. The first is the cost of operating separate organizational units established specifically to administer federal grants and contracts; the second covers administrative activities outside of the separate units which benefit federally sponsored programs exclusively. This latter component is based, to a large extent, on faculty effort reporting and is thus subject to the same controversy as departmental administration.

Reimbursement for student services administration is not large enough at most universities to be significant.

Finally, there is the general administration category, which includes the costs of the central administration of the institutions involved and various other miscellaneous administrative items. Although it currently represents about 15 percent of indirect reimbursements, the general administration category has not been subject to significant controversy. Furthermore, it has not shown the sort of growth recently characteristic of the other administrative pools.

4. Diversity and Variation in Administrative Rates

Clearly, one of the strengths of the U.S. higher education system is the diversity that has allowed the system to develop centers of excellence, institutions with unique capabilities and a degree of accessibility unmatched in the world.

The universities contend that the present indirect cost reimbursement mechanism, by basing reimbursements on documented costs, is flexible enough to reflect and help maintain this diversity. The present cost allocation mechanism, however, stimulates confusion over the manner in which already controversial costs are reimbursed. Similar administrative costs can be charged to a number of different cost pools—direct or indirect, departmental administration or sponsored projects administration, etc. A paper prepared for the Panel by the Council on Governmental Relations (COGR), an association of university financial officers lists, by example, a number of costs that are classified differently at different institutions. Many of the differences in classification reflect differences in internal organization. As the paper notes,

> Essentially, the variety of methods used to group and allocate costs was basically the result of the variety of organizational structure.

These structures in turn reflect variation in an enormous number of individual institutional characteristics.

One of the questions the COGR analysis sought to answer was why many seemingly similar institutions have such dissimilar administrative cost rates in both the aggregate and within specific component pools. It concluded that there are four principal reasons for differences in aggregate administrative cost rates from institution to institution:

1. Similar administrative costs may be charged indirectly at one university and directly at another.
2. The same costs may be regarded as administrative costs at one university and as operational or plant costs at another (more likely, as one administrative pool at one university, another at another).
3. Excluding costs from the aggregate direct category can cause the same amount of administrative costs to be reflected in a different ICR rate.
4. How vigorously an institution accounts for costs, and negotiates reimbursements, may affect the amount charged to administrative pools.

The first three of these reasons, according to the COGR report:

> result in shifting of costs among various indirect and direct cost categories; the remaining reason results in modifications in the total amount of costs claimed.

The primary reason why the total administrative costs charged differ from institution to institution is simply that institutions differ in the degree of vigor they apply to accounting for, and charging for those costs. The Panel concludes that there does not appear to be as much variation in actual administrative costs as the diversity in the system might suggest.

5. The GAO Recommendation

To resolve some of the current controversy, the 1984 GAO report recommends that OMB amend Circular A-21 to fix reim-

bursements for departmental administration as a percentage of direct reimbursements, replacing the "cost reimbursement" method now used. The reimbursement, suggests the GAO report, could vary on an institution-by-institution basis, depending on their individual circumstances, but should not rely on effort reporting to represent those circumstances. The reimbursement should represent a reasonable amount needed for effective research administration at the departmental level of each institution. The GAO report followed a similar proposal by HHS contained in a 1983 report to Congress.

6. The Stanford and Yale Agreements

In the meantime, two universities, Stanford and Yale, have undertaken to deal with the problem individually and ease their paperwork burdens, reduce their administrative costs and eliminate some of the adversity created by the ongoing indirect cost controversy. Each university negotiated a fixed rate for departmental administration in exchange for reducing effort reporting requirements. Both agreements have finite durations: Stanford's must be renegotiated after five years, Yale's after four. Both institutions, according to the NAS Workshop on Effort Reporting in A-21 made financial concessions in their agreements, but did so on the stated grounds that the financial loss was outweighed by the intangible gains in the morale and spirit among researchers, and a greater collegiality among researchers and administrators.

APPENDIX G

A Summary History of Indirect Costs

1950-1965

Cost principles for indirect cost reimbursement formally worked out, and published in a Bureau of the Budget Circular A-21 in 1958. The Department of Health, Education and Welfare set a fixed upper limit on indirect cost recovery for grants. This was 8 percent initially, changed to 15 percent in 1958, and 20 percent in 1963.

1966

Indirect cost ceiling removed. Cost-sharing required by law in the Department of Health, Education and Welfare Appropriations Act.

1975-1979

Sixth revision of Circular A-21. Revised requirements for effort reporting and standard basis for distributing costs among projects.

1982

Seventh revision of Circular A-21. Effort reporting requirements eased, and interest expense made allowable in specific circumstances.

APPENDIX H

NUMERICAL DATA FOR FIGURE 1 NOT AVAILABLE.

NUMERICAL DATA FOR FIGURE 2

National R&D Funding Trends: 1953-1984

(Constant 1972 dollars in billions)

Year	Total R&D	Federal R&D	Nonfederal R&D
1953	8.6	4.6	4.0
1954	9.4	5.2	4.2
1955	10.1	5.7	4.4
1956	13.3	7.7	5.6
1957	15.0	9.4	5.6
1958	16.2	10.2	6.0
1959	18.3	11.9	6.4
1960	19.6	12.7	6.9
1961	20.6	13.3	7.3
1962	21.7	14.0	7.7
1963	23.7	15.6	8.1
1964	25.9	17.2	8.7
1965	26.9	17.4	9.5
1966	28.4	18.2	10.2
1967	29.2	18.2	11.0
1968	29.8	18.1	11.7
1969	29.6	17.2	12.4
1970	28.6	16.3	12.3
1971	27.8	15.6	12.2
1972	28.5	15.8	12.7
1973	29.1	15.6	13.5
1974	28.8	14.8	14.0
1975	28.2	14.5	13.7
1976	29.5	15.1	14.4
1977	30.5	15.4	15.1
1978	32.0	15.9	16.1
1979	33.6	16.4	17.2
1980	35.1	16.5	18.6
1981	36.7	17.1	19.6
1982	38.2	17.5	20.7
1983	40.1	18.6	21.5
1984	42.8	19.9	22.9

Source: National Science Foundation. *National Patterns of Science and Technology Resources, 1984.*

NUMERICAL DATA FOR FIGURE 3

FEDERAL EXPENDITURES ON UNIVERSITY RESEARCH: 1953-1984

(Constant 1972 dollars in millions)

Year	All Research	Basic Research	Applied Research	Development
1953	234	124	96.80	13.00
1954	268	151	113.60	16.70
1955	277	169	95.10	13.10
1956	339	207	108.10	23.80
1957	352	238	95.30	19.00
1958	384	270	96.00	18.10
1959	453	335	99.20	19.20
1960	590	435	129.00	26.20
1961	722	551	141.50	28.80
1962	869	682	154.00	32.60
1963	1062	852	178.70	30.70
1964	1260	1055	175.00	30.00
1965	1444	1182	212.00	49.70
1966	1643	1313	252.70	76.80
1967	1783	1422	280.90	79.70
1968	1905	1515	307.00	83.00
1969	1845	1475	283.00	86.50
1970	1804	1419	293.30	91.90
1971	1795	1405	304.10	86.40
1972	1795	1420	320.00	55.00
1973	1877	1375	420.00	63.70
1974	1766	1323	380.60	61.60
1975	1819	1347	410.20	62.00
1976	1893	1391	441.20	65.70
1977	1946	1433	433.40	79.90
1978	2034	1505	447.40	82.00
1979	2200	1574	528.10	97.90
1980	2295	1598	580.10	116.50
1981	2338	1664	556.50	115.30
1982	2295	1640	541.80	113.00
1983	2259	1625	518.70	115.20
1984	2429	1780	534.30	114.80

Source: *National Patterns of R&D Resources; Funds and Manpower in the United States, 1953-1975; National Patterns of Science and Technology Resources, 1984.*

NUMERICAL DATA FOR FIGURE 4

NATIONAL EXPENDITURES FOR R&D BY SOURCE: 1966-1984

(Constant 1972 dollars in millions)

YEAR	FEDERAL GOVERNMENT	UNIVERSITIES and COLLEGES
1966	18,180	395
1967	18,176	434
1968	18,107	474
1969	17,209	488
1970	16,316	506
1971	15,615	553
1972	15,808	574
1973	15,594	588
1974	14,826	604
1975	14,537	608
1976	15,072	614
1977	15,382	630
1978	15,878	639
1979	16,407	734
1980	16,541	745
1981	17,124	781
1982	17,841	806
1983	18,622	855
1984	19,577	916

Source: *National Patterns of Science and Technology Resources, 1984*

NUMERICAL DATA FOR FIGURE 5

PROPORTION OF NSF AND NIH GRANT FUNDS ALLOCATED FOR PERMANENT LABORATORY EQUIPMENT

YEAR	% of Total Dollars Awarded NSF	NIH
1966	11.2	11.7*
1967	8.6	11.8*
1968	7.5	9.5*
1969	7.0	7.5*
1970	6.1	5.9*
1971	6.3	6.2*
1972	5.6	6.6*
1973	5.5	4.9*
1974	5.4	5.7*
1975	7.4	4.6
1976	7.0	3.9
1977	6.2	4.3
1978	7.3	4.4
1979	8.4	4.6
1980	7.9	3.9
1981	8.6	3.3
1982	9.0	3.2
1983(est)	10.3	3.4
1984(est)	13.9	3.6

*Includes only data from the National Cancer Institute, the National Institute of General Medical Sciences, and the National Heart and Lung Institute.

†The NSF data is obtained from *Science Indicators, 1974*, and Jim Hoehn, personal communication. The NIH data through 1974 is obtained from *Science Indicators, 1974*. After 1974, the data is from internal NIH files, and reflects the total contribution of grant funds to equipment.

NUMERICAL DATA FOR FIGURE 6 NOT AVAILABLE.

NUMERICAL DATA FOR FIGURE 7

FEDERAL SUPPORT FOR RESEARCH AND DEVELOPMENT: 1953-1984

(constant 1972 dollars in millions)

Year	Total	Basic	Applied	Development
1953	4,649	421	1,260	2,968
1954	5,257	444	1,377	3,436
1955	5,754	469	1,381	3,905
1956	7,725	548	1,609	5,568
1957	9,411	627	1,987	6,796
1958	10,280	696	2,222	7,361
1959	11,936	903	2,405	8,629
1960	12,673	1,030	2,442	9,201
1961	13,372	1,214	2,604	9,554
1962	14,069	1,546	3,015	9,508
1963	15,671	1,830	3,080	10,761
1964	17,264	2,194	3,442	11,628
1965	17,443	2,415	3,379	11,649
1966	18,180	2,571	3,359	12,250
1967	18,176	2,774	3,398	12,004
1968	18,108	2,837	3,411	11,860
1969	17,209	2,829	3,221	11,159
1970	16,316	2,733	3,377	10,209
1971	15,615	2,644	3,141	9,830
1972	15,808	2,633	3,104	10,071
1973	15,594	2,589	3,234	9,771
1974	14,826	2,589	3,124	9,113
1975	14,537	2,540	3,173	8,824
1976	16,072	2,604	3,434	9,034
1977	15,382	2,718	3,405	9,259
1978	15,878	2,956	3,478	9,444
1979	16,407	3,085	3,592	9,730
1980	16,541	3,128	3,709	9,704
1981	17,124	3,199	3,831	10,094
1982	17,841	3,160	3,719	10,962
1983	18,622	3,205	3,738	11,679
1984	19,577	3,427	3,701	12,449

Source: *National Patterns of R&D Resources: Funds and Manpower in the United States, 1953-1975, National Patterns of Science and Technology Resources, 1984*

NUMERICAL DATA FOR FIGURE 8

FEDERAL NONDEFENSE R&D EXPENDITURES: 1975-1984

(Constant 1972 dollars in millions)

Year	Basic Research	Applied Research	Development
1975	1871.6	3188.6	3758.6
1976	1843.7	2758.8	3803.0
1977	2060.6	2793.2	4061.4
1978	2186.5	2987.6	4326.5
1979	2276.9	2936.6	4355.6
1980	2317.0	2915.5	3650.9
1981	2273.7	2651.4	3578.4
1982	2317.7	2549.7	2778.4
1983	2451.1	2617.1	2117.2
1984	2538.0	2360.1	2062.8

Source: *National Patterns of Science and Technology Resources, 1984*

NUMERICAL DATA FOR FIGURE 9

PERCENT OF NATIONAL SCIENCE AND ENGINEERING DOCTORAL DEGREES RECEIVED BY NON-RESIDENT FOREIGNERS, SELECTED DISCIPLINES: 1960-1984

Year	Phys. Sci.	Earth, Marine, Env. Sci.	Math./Comp. Sciences	Agricul. Sciences	Biolog. Sciences	Total Eng.
1960	8.89	13.83	15.12	21.98	11.87	16.24
1961	10.70	13.82	13.25	21.00	13.90	16.38
1962	11.20	9.23	16.75	23.82	14.38	17.92
1963	10.78	15.83	12.62	19.31	13.84	15.84
1964	10.41	12.25	13.60	26.11	14.68	14.84
1965	11.24	12.26	11.09	29.86	15.63	15.38
1966	11.52	12.87	12.61	30.38	14.66	16.73
1967	11.57	14.11	11.08	30.03	12.62	15.70
1968	10.25	14.93	11.53	28.65	12.73	15.27
1969	9.77	15.38	10.65	27.93	10.99	14.08
1970	9.32	13.92	10.93	24.75	10.74	13.71
1971	9.19	8.15	12.27	26.24	8.53	14.80
1972	10.59	10.59	13.19	27.16	8.47	14.81
1973	12.68	11.51	14.03	27.36	12.16	18.48
1974	13.16	16.05	18.49	33.04	10.41	22.37
1975	14.88	14.98	17.17	29.50	9.06	27.14
1976	15.06	14.88	18.24	30.96	8.76	28.68
1977	14.92	14.40	17.63	32.86	9.13	29.24
1978	15.20	10.91	18.87	31.30	8.30	31.69
1979	15.51	10.99	21.75	30.99	8.14	32.73
1980	16.89	12.73	18.91	32.45	7.78	34.32
1981	16.82	14.57	23.54	33.09	7.57	37.26
1982	18.78	12.32	26.70	27.33	8.81	38.92
1983	19.23	16.64	28.47	30.24	8.61	42.07
1984	19.82	17.26	32.29	31.29	9.29	43.49

Source: "Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook," Prepared by: National Science Foundation, Directorate for Scientific, Technological, and International Affairs, Division of Science Resources Studies, Table B-21.

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